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Heating · Piping and Air Conditioning

MAY 31 1930

June, 1930

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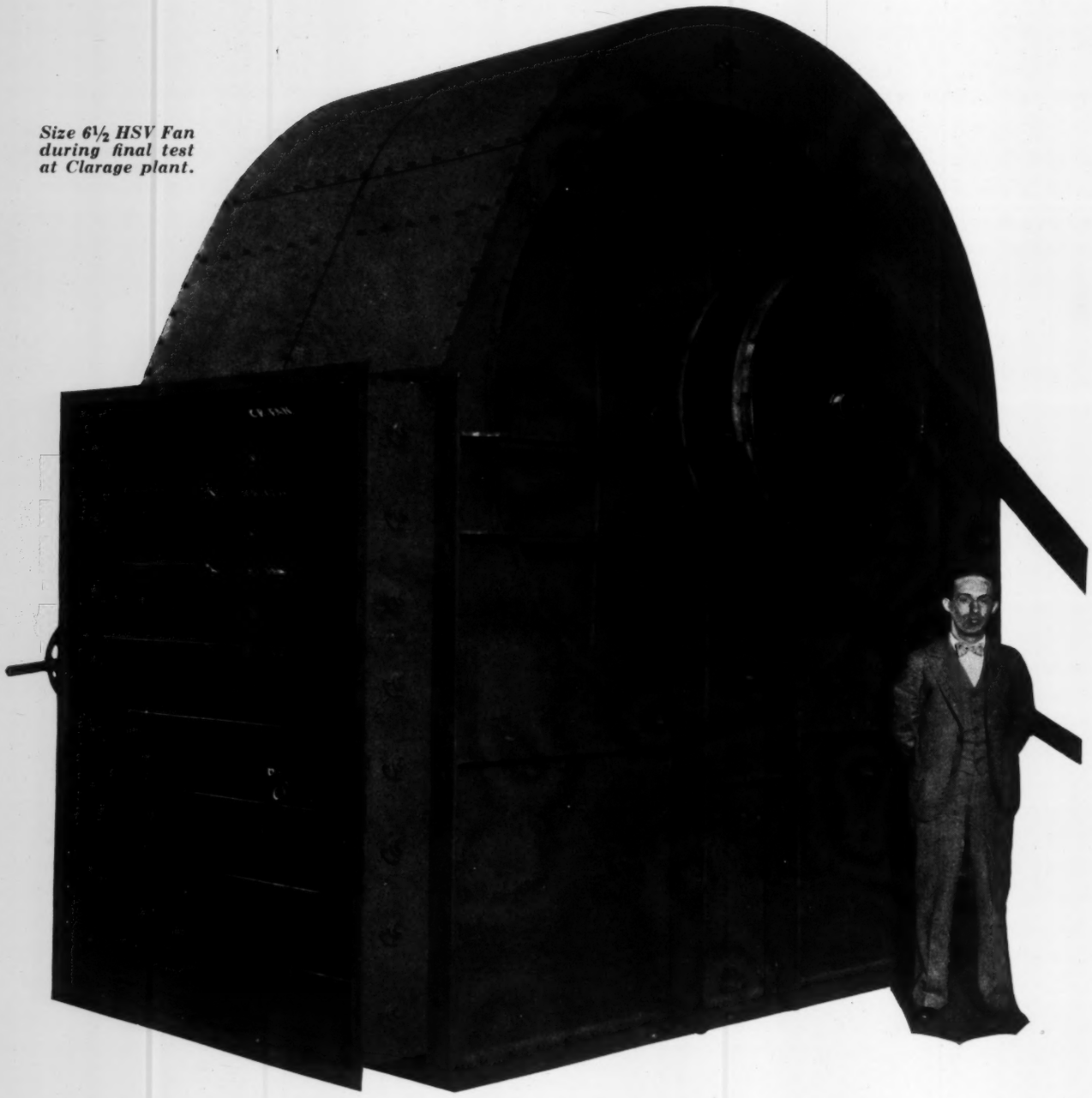

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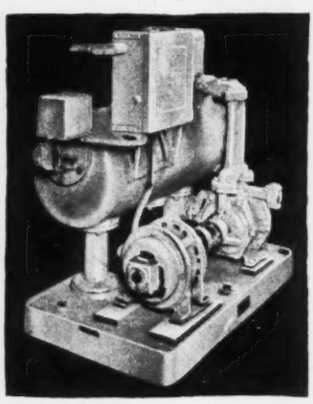

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Heating · Piping and Air Conditioning

Vol. II June, 1930 No. 6

Viscosity of Refrigerants

By John C. Reed and Edgar E. Ambrosius

WHEN a fluid is flowing in a pipe, frictional resistance is encountered. Not only is there resistance between the fluid and pipe, but also within the various layers of the fluid itself. This latter effect is known as internal friction and is proportional to the viscosity[1] *of the fluid in question.*

The fact is now well established that all fluids obey the same fundamental laws of flow, provided their viscosities are known, and it was for this reason that this data on viscosity of refrigerants was compiled.

The purpose of this paper is to present in condensed form the available data relative to the viscosity of several refrigerants. The data is presented in both tabular and graphical form, in order to suit the needs of those interested.

Viscosity—General Theory[2]

The viscosity of a fluid, as stated by G. Martin, in his treatise on "Chemical Engineering," is the property to which is due the internal resistance offered to the motion of the fluid at any point with velocity different from that at an immediately adjacent point. According to Maxwell: The viscosity of a substance is measured by the tangential force on a unit area of either of two horizontal planes at a unit distance apart required to move one plane with unit velocity in reference to the other plane, the space between being filled with the viscous substance.

The coefficient of viscosity of a fluid may be expressed as the numerical value of the tangential force on a unit area of either of two parallel planes a unit distance apart when the space between these planes is filled with the fluid in question and one of the planes moves with unit velocity in its own plane relative to the other.

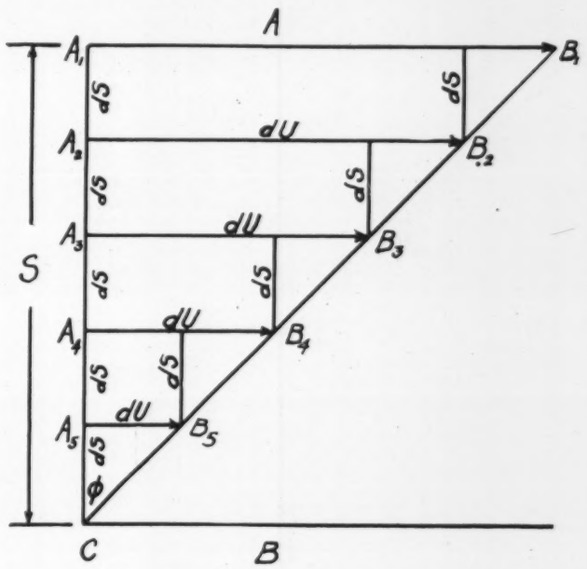


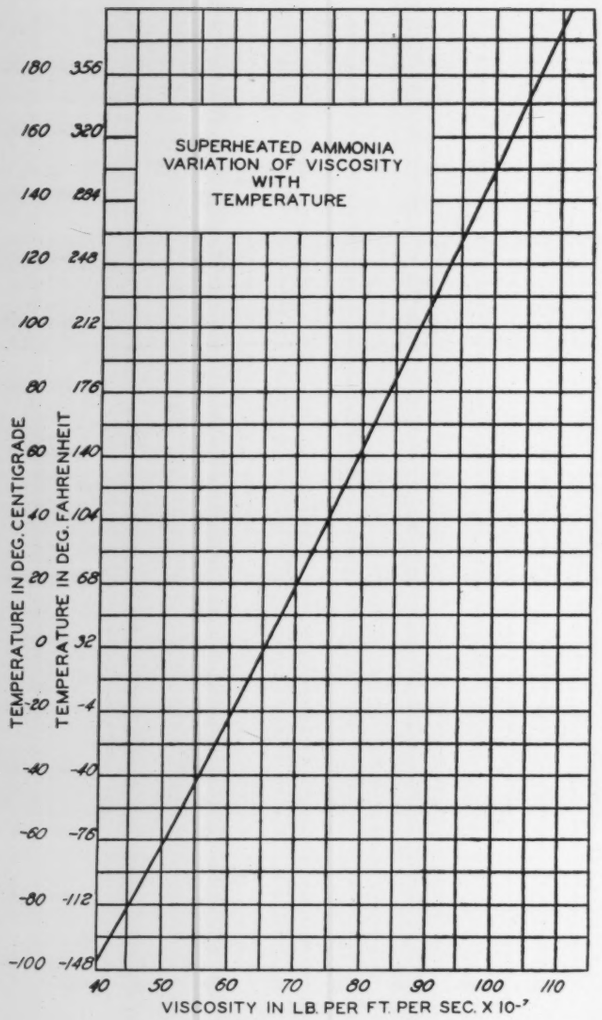
FIG. 1—DERIVATION OF FORMULA AND DIMENSIONS OF VISCOSITY

A general formula and the dimensions of viscosity may be derived by considering two parallel planes A and B, letting S be their distance apart, as represented in Fig. 1.

[1] The term viscosity, as used in this paper, refers in all cases to the absolute viscosity.

[2] Based on a treatment of this subject by the authors in "Flow of Superheated Ammonia in One Inch Extra Heavy Black Steel Pipe" in *Refrigerating Engineering*, February, 1930.

"The viscosity of all refrigerants should receive more attention because their viscosities may be such that if studied more carefully it might be determined which could be circulated and used more efficiently from a flow view-point."



Let a shearing force F per unit area be applied to A, and give it a uniform velocity U, in reference to B, then the velocity of each stratum between A and B will be proportional to its distance from B.

If $A_1 B_1$, $A_2 B_2$ etc., represent the velocities of the respective layers of fluid between the two planes A and B at the distance from B of $A_1 C$, $A_2 C$, etc.

Then, $$\frac{A_1 B_1}{A_1 C} = \frac{A_2 B_2}{A_2 C} = \tan \phi$$

Since $A_1 B_1 = U$ and the distance between the successive layers is dS, and the corresponding small difference in velocity is dU.

$$\frac{U}{S} = \frac{dU}{dS}$$

The rate of shear $\frac{dU}{dS}$ is therefore constant through a homogeneous fluid according to the conditions herein stated and is equal to tan ϕ.

The force, F, required to maintain the plane A in a state of uniform velocity U must be opposed by an equal and opposite force. (Newton's second law). This opposing force is due to internal friction.

TABLE 1—VISCOSITY (N) OF NH_3 (AMMONIA)

TEMP.		VISCOSITY		AUTHORITY
C.	F.	C. G. S.	ENGLISH	
— 78.5	—109.3	672	45.15	International Critical Tables
— 77	—106.6	690	46.37	Chemical Engineering—Martin
.....	.....	686	46.20	Landolt-Bornstein—H. Vogel
.....	.....	678	45.60	Annalen Der Physik—H. Vogel
0	32	960	64.52	Smithsonian Physical Tables
.....	.....	930	62.50	Chemical Engineering—Martin
.....	.....	957	64.35	Landolt-Bornstein—Graham
.....	.....	926	62.20	Landolt-Bornstein—H. Vogel
.....	.....	957	64.35	Annalen Der Physik—Graham
.....	.....	957	64.35	Encyclopaedia Britannica
.....	.....	960	64.52	Annalen Der Physik—Thomson
.....	.....	959	64.45	Annalen Der Physik—Mittel
.....	.....	926	62.20	Annalen Der Physik—H. Vogel
.....	.....	980	65.82	Calculated—O. E. Meyer
.....	.....	918	61.70	International Critical Tables
13	55.4	1005	67.45	Landolt-Bornstein—E. Thomson
15	59.0	1005	67.45	Proc. Phy. Soc. Lon.—Edwards-Worswick
20	68.0	1080	72.58	Chemical Engineering—Martin
.....	.....	1080	72.58	Landolt-Bornstein—Graham
.....	.....	1080	72.58	Calculated—O. E. Meyer
.....	.....	1080	72.58	Smithsonian Physical Tables
100	212	1300	87.36	Chemical Engineering—Martin
.....	.....	1303	87.60	Landolt-Bornstein—Rankin-Smith
.....	.....	1303	87.60	Smithsonian Physical Tables
.....	.....	1295	87.00	Proc. Phy. Soc. Lon.—Edwards-Worswick
.....	.....	1293	86.90	International Critical Tables
183.8	382.8	1612	108.30	Proc. Phy. Soc. Lon.—Edwards-Worswick

C. G. S. units in this table are in Centipoises $\times 10^{-7}$. English units are in $\frac{\text{Lb.}}{\text{Ft.} \times \text{Sec.}} \times 10^{-7}$.

Let N be the coefficient of viscosity.

$$N = \frac{\text{Force}}{\text{Rate of shear}} = \frac{F}{\frac{U}{S}} = \frac{F}{\frac{dU}{dS}}$$

$$N = F\frac{dS}{dU}$$

$$F = N\frac{dU}{dS}$$

The tangential force per unit area required to maintain a layer of fluid in a state of uniform speed U is equal to the coefficient of viscosity times the rate of change of velocity with distance.

Adopting

M = Mass

L = Length, in ft.

U = Speed, in ft. per sec.

T = Time, in sec.

The coefficient of viscosity, N, becomes,

$$N = \frac{\text{Force per unit area} \times \text{distance}}{\text{Velocity}}$$

$$= \frac{FS}{U}$$

TABLE 2—VISCOSITY (N) OF SO_2 (SULPHUR DIOXIDE)

TEMP.		VISCOSITY		AUTHORITY
C.	F.	C. G. S.	ENGLISH	
0	32	1168	78.50	Encyclopaedia Britannica
.....	.....	1230	82.66	Chemical Engineering—Martin
.....	.....	1225	82.35	Landolt-Bornstein—Graham
.....	.....	1183	79.50	Landolt-Bornstein—H. Vogel
.....	.....	1170	78.60	International Critical Tables
18	64.4	1242	83.50	International Critical Tables
20	68	1380	92.74	Chemical Engineering—Martin
.....	.....	1380	92.74	Landolt-Bornstein—Graham
100	212	1616	108.60	International Critical Tables

C. G. S. units in this table are in Centipoises $\times 10^{-7}$. English units are in $\frac{\text{Lb.}}{\text{Ft.} \times \text{Sec.}} \times 10^{-7}$.

TABLE 3—VISCOSITY (N) OF C_4H_{10} (BUTANE)

TEMP.		VISCOSITY		AUTHORITY
C.	F.	C. G. S.	ENGLISH	
14.7	57.65	840.4	56.50	Landolt-Bornstein—Knenen-Wisser
.....	.....	832.0	55.90	International Critical Tables
16	61.16	841.3	56.55	Landolt-Bornstein—Knenen-Wisser
.....	.....	833.0	56.00	International Critical Tables
100	212.00	1092	73.40	Landolt-Bornstein—Knenen-Wisser
.....	.....	1082	72.70	International Critical Tables

C. G. S. units in this table are in Centipoises $\times 10^{-7}$. English units are in $\frac{\text{Lb.}}{\text{Ft.} \times \text{Sec.}} \times 10^{-7}$.

TABLE 4—VISCOSITY (N) OF C_2H_6 (ETHANE)

TEMP.		VISCOSITY		AUTHORITY
C.	F.	C. G. S.	ENGLISH	
—78.5	—109.3	634	42.58	International Critical Tables
—78.0	—108 4	640	43.01	Chemical Engineering—Martin
0	32	850	57.12	Chemical Engineering—Martin
.....	.....	848	56.95	International Critical Tables

C. G. S. units in this table are in Centipoises $\times 10^{-7}$. English units are in $\frac{\text{Lb.}}{\text{Ft.} \times \text{Sec.}} \times 10^{-7}$.

$$= \frac{MU}{TL^2} \times \frac{L}{U}$$

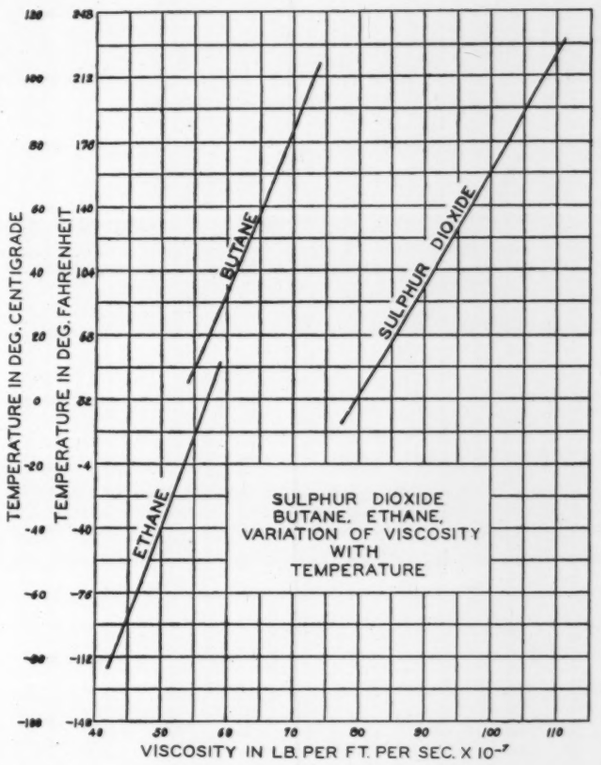
$$N = \frac{M}{LT}$$

Viscosity—Units

In the experimental records consulted for values of viscosity for the refrigerants considered in this paper, it was found that the values were almost invariably given in centipoises. That is, most of the values are given in the C. G. S. system of units. It is often more desirable for the engineer to have the viscosity expressed in English units. The conversion may be carried out in the following manner.

$$\text{Viscosity} = \frac{\text{Mass}}{\text{Length} \times \text{Time}}$$

In the C. G. S. system of units this becomes,



$$\text{Viscosity} = \frac{\text{Grams}}{\text{Centimeters} \times \text{Seconds}}$$

While in the English system of units,

$$\text{Viscosity} = \frac{\text{Pounds}}{\text{Feet} \times \text{Seconds}}$$

Hence, one unit of viscosity in the C. G. S. system equals

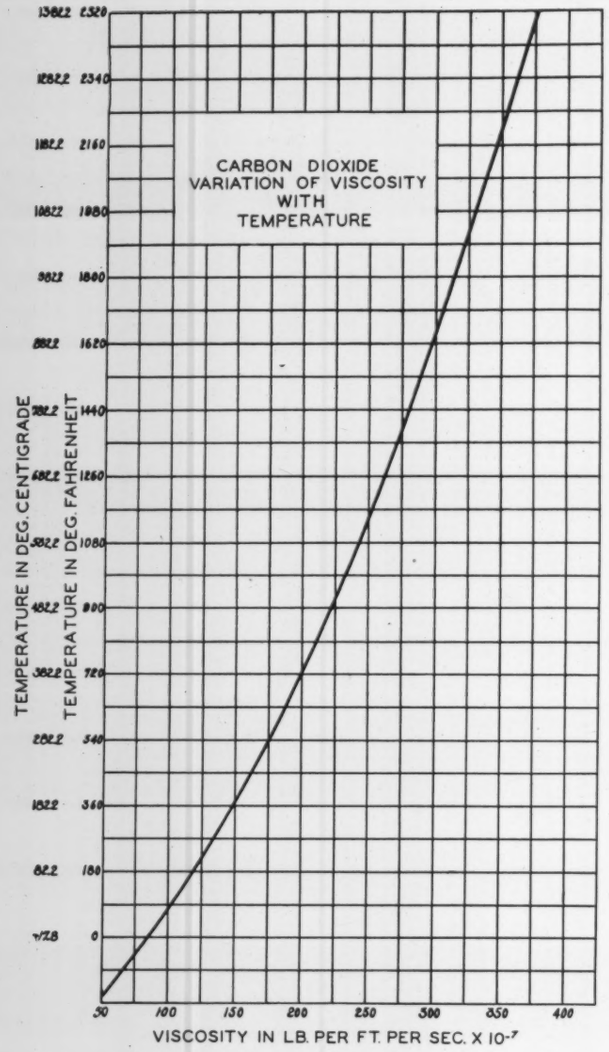
$$\frac{1 \text{ gram}}{1 \text{ centimeter} \times 1 \text{ second}}$$

$$= \frac{\frac{1}{453.6 \text{ pounds}}}{\frac{1}{30.48 \text{ ft.}} \times 1 \text{ second}} = \frac{30.48}{453.6} \times \frac{1 \text{ pound}}{1 \text{ ft.} \times 1 \text{ second}}$$

Clearing the equation, one C. G. S. unit of viscosity = 0.0672 $\times$ one English unit; i. e., to convert a C. G. S. unit of viscosity into an English unit, multiply the C. G. S. unit by the factor 0.0672. Conversely, to convert an English unit into a C. G. S. unit multiply the English unit by the factor 14.88 which equals $\frac{1}{0.0672}$

Quite an extensive search was made for material pertaining to the viscosity of refrigerants. The data presented herein comprises practically all the data available concerning the more important refrigerants.

The term, or unit, kinematic viscosity is sometimes used. Kinematic viscosity is the ratio of the absolute viscosity to the density and may be represented by a single symbol.



Viscosity of Gases

The viscosities of gases, unlike those of liquids, increase with temperature, as is shown in the curves. In order that a direct comparison may be made between liquids and gases, a graph showing variation of temperature against viscosity for water is incorporated in this paper. The curve was plotted from values given in Landolt-Bornstein.

Maxwell, in developing the kinetic theory of gases, deduced an expression from which it follows that:

(1) The viscosity of a gas is independent of the pressure.

(2) It increases with rising temperature in a linear ratio with the square root of the absolute temperature.

This striking prediction has also been verified experimentally. Actually, the viscosity is not proportional to the square root of the absolute temperature as theory requires, but increases much more rapidly.

The discrepancy in the case of most gases has been explained by Sutherland, who found the actual law of the variation. According to Sutherland, the influence of the temperature on the viscosity may be represented by the following formula:

TABLE 5—VISCOSITY (N) OF CO_2 (CARBON DIOXIDE)

TEMP. C.	TEMP. F.	VISCOSITY C. G. S.	VISCOSITY ENGLISH	AUTHORITY
—78.4	—109.12	1033	69.20	Landolt-Bornstein—H. Vogel
—78.0	—108.4	1030	69.21	Chemical Engineering—Martin
—21.5	—6.7	1278	85.90	Landolt-Bornstein—Obermayer
—21.0	—5.8	1290	86.70	Chemical Engineering—Martin
—20.7	—5.26	1294	87.00	Landolt-Bornstein—Breitenbach
0	32	1414	95.00	Landolt-Bornstein—Graham
.....	.....	1380	92.80	Landolt-Bornstein—H. Vogel
.....	.....	1390	93.40	Chemical Engineering—Martin
.....	.....	1382	92.90	Encyclopaedia Britannica
12.0	53.60	1436	96.50	Landolt-Bornstein—E. Tohomsen
12.6	54.68	1450	97.50	Landolt-Bornstein—J. H. T. Roberts
12.8	55.04	1422	95.60	Landolt-Bornstein—Schumann
14.0	57.20	1449	97.40	Landolt-Bornstein—Obermayer
15.0	59.0	1469	98.70	Landolt-Bornstein—Puluj
.....	.....	1520	102.20	Landolt-Bornstein—Kundt-Warburg
.....	.....	1457	98.00	Landolt-Bornstein—Breitenbach
.....	.....	1464	98.40	Landolt-Bornstein—Breitenbach
.....	.....	1460	98.11	Chemical Engineering—Martin
18.00	64.40	1605.6	107.90	Landolt-Bornstein—Zemplen
18.26	64.87	2073.0	139.40	Landolt-Bornstein—Zemplen
18.86	65.95	1686.5	113.40	Landolt-Bornstein—Zemplen
19.90	67.82	1528	102.70	Landolt-Bornstein—Puluj
20.00	68	1568	105.40	Landolt-Bornstein—Lang
.....	.....	1600	107.50	Landolt-Bornstein—Graham
.....	.....	1600	107.50	Landolt-Bornstein—Meyer-Springmuhl
.....	.....	1614	108.50	Landolt Bornstein—Maxwell
.....	.....	1600	107.50	Chemical Engineering—Martin
53.5	128.3	1638	110.10	Landolt-Bornstein—Obermeyer
54.0	129.2	1640	110.20	Chemical Engineering—Martin
99.0	210.2	1860	125.00	Chemical Engineering—Martin
99.1	210.38	1861	125.00	Landolt-Bornstein—Breitenbach
100.0	212.0	1972	132.50	Landolt-Bornstein—Schumann
162.0	323.6	2140	143.80	Chemical Engineering—Martin
182.0	359.6	2220	149.20	Chemical Engineering—Martin
222.0	431.6	2380	159.90	Chemical Engineering—Martin
240.0	464.0	2460	165.30	Chemical Engineering—Martin
302.0	575.6	2680	180.10	Chemical Engineering—Martin
426.7	800.0	3110	209.00	Chemical Engineering—Martin
537.8	1000.0	3470	230.00	Chemical Engineering—Martin
815.6	1500.0	4280	288.00	Chemical Engineering—Martin
926.7	1700.0	4560	306.00	Chemical Engineering—Martin
1093.3	2000.0	4960	333.00	Chemical Engineering—Martin
1426.7	2600.0	5720	384.00	Chemical Engineering—Martin

C. G. S. units in this table are in Centipoises $\times 10^{-7}$. English units are in $\frac{\text{Lb.}}{\text{Ft.} \times \text{Sec.}} \times 10^{-7}$.

$$N = \frac{N_o T_o + C}{T + C} \left(\frac{T}{T_o} \right)^{\frac{3}{2}}$$

Where N and N_o are the viscosities at the absolute temperatures T and T_o respectively, and C is "Sutherland Constant."

C may be readily determined graphically from a number of observations by plotting T against $\frac{T^{\frac{3}{2}}}{N}$ since we have

$$T = \left[\frac{T^{\frac{3}{2}}}{N} \right] \left[\frac{N_o \left(1 + \frac{C}{T_o}\right)}{T_o^{\frac{1}{2}}} \right] - C$$

TABLE 6—VISCOSITY (N) OF CH_3Cl (METHYL CHLORIDE)

TEMP.		VISCOSITY		AUTHORITY
C.	F.	C. G. S.	ENGLISH	
− 15.3	4.46	936	62.90	Landolt-Bornstein—Breitenbach
.....	.....	920	61.80	International Critical Tables
0	32	1025	68.90	Landolt-Bornstein—Graham
.....	.....	978	65.70	Landolt-Bornstein—H. Vogel
.....	.....	960	64.50	International Critical Tables
15	59	1052	70.70	Landolt-Bornstein—Breitenbach
.....	.....	1040	69.90	International Critical Tables
20	68	1160	78.00	Landolt-Bornstein—Graham
99.1	210.38	1384	93.00	Landolt-Bornstein—Breitenbach
.....	.....	1370	92.10	International Critical Tables
182.4	360.32	1706	114.60	Landolt-Bornstein—Breitenbach
.....	.....	1680	112.70	International Critical Tables
302	575.60	2139	143.60	Landolt-Bornstein—Breitenbach
.....	.....	2110	141.70	International Critical Tables

C. G. S. units in this table are in Centipoises $\times 10^{-7}$. English units are in $\frac{\text{Lb.}}{\text{Ft.} \times \text{Sec.}} \times 10^{-7}$.

TABLE 7—VISCOSITY (N) OF C_2H_5Cl (ETHYL CHLORIDE)

TEMP.		VISCOSITY		AUTHORITY
C.	F.	C. G. S.	ENGLISH	
0	32	937	63.00	International Critical Tables

C. G. S. units in this table are in Centipoises $\times 10^{-7}$. English units are in $\frac{\text{Lb.}}{\text{Ft.} \times \text{Sec.}} \times 10^{-7}$.

Simplifying, we have

$$N_t = N_o \left[\frac{273 + C}{\theta + C}\right] \left[\frac{\theta}{273}\right]^{\frac{3}{2}}$$

θ = absolute temperature, in degrees Centigrade
C = Sutherland's constant
N_o = Viscosity at 0 deg. in C. G. S. units
N_t = Viscosity at t deg. in C. G. S. units

That is, the viscosity at any temperature may be calculated if the value is known for zero degrees and Sutherland's constant is also known.

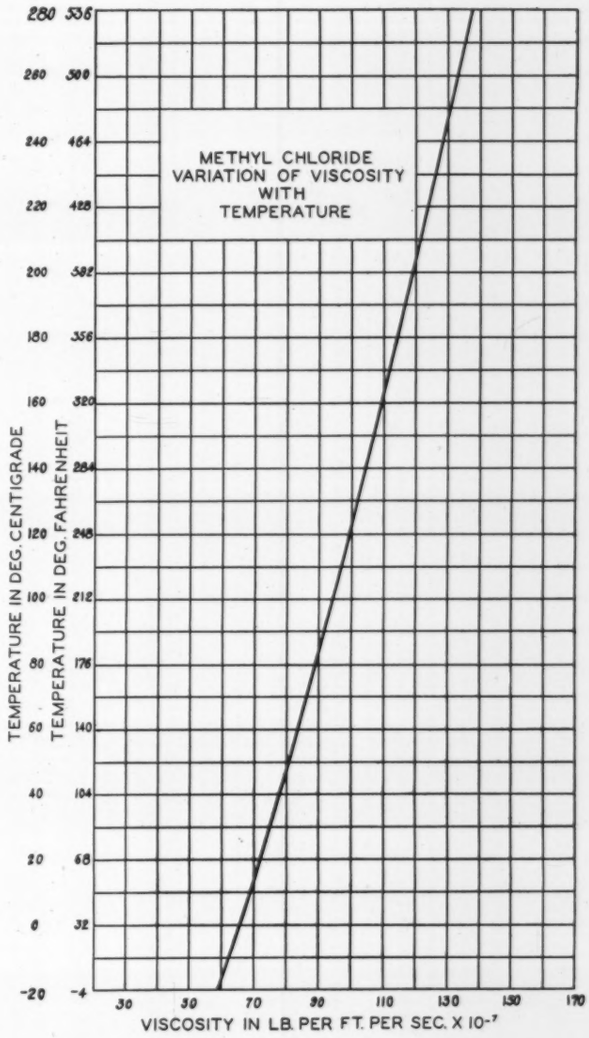
The following are values of C for the refrigerants considered.

Gas	C	Authority
NH_3	370	International Critical Tables
SO_2	416	International Critical Tables
CO_2	274	Rankine and Smith
	240	Breitenbach
CH_3Cl	454	International Critical Tables
Air	124	Martin

The value of Sutherland's work may be realized by noting that the experimental values and those calculated by Sutherland's equation check remarkably well. This checking of values shows that Sutherland's formula can be applied safely in viscosity calculations.

An extensive search was made for more data concerning ethane, butane, propane and ethylchloride, but only the values in the tables could be found.

In observing values for the viscosity of refrigerants it was noted that several authorities stated that the viscosity of a gas was practically independent of pressure. Vogel says that the viscosity is independent of pressure

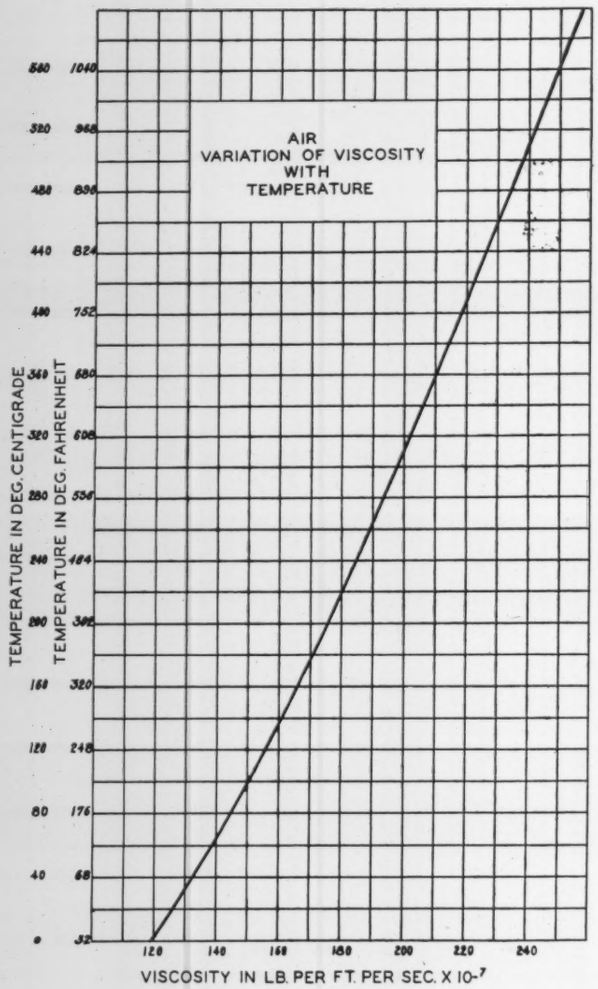


and he was the only experimenter found, who, while observing data for viscocity determinations, ever recorded pressures.

The *International Critical Tables* state that, neglecting slip, the viscosity of a gas is independent of pressure. Bingham says, "In analyzing the theory of viscosity of gases, it was seen at once the viscosity of gases should be independent of pressure." Also, Bingham points out that Warburg and others proved that the viscosity of a gas fluctuates with the pressure in the neighborhood of the critical temperature. In commercial refrigerating practice, the refrigerants are dealt with far removed from the critical temperature, (except CO_2 and C_2H_6); therefore, it may be safely assumed that the viscosity varies independently of pressure. That is, the viscosity increases as the temperature increases regardless of pressure.

The critical temperature of CO_2 is rather low, being about 88 F and one might expect a slight inflection in a curve showing temperature against viscosity in the vicinity of the critical temperature. However, as may be seen by examining the curve for carbon dioxide, there is no inflection at the critical temperature. It is the authors' belief that, for commercial purposes, the viscosity of CO_2 may be assumed to vary independent of the pressure.

Ethane also has a low critical temperature, about 90 F.



Sufficient data is not available to observe the behavior of ethane in the vicinity of its critical temperature.

Bingham in his "Fluidity and Plasticity" says, "The conclusion has been reached that the viscosity is a fundamental property independent of the particular method used in its measurement." For example, Milliken, in 1913, brought together the results of viscosity determinations by five different methods for air at 23 C and found them to check within less than 0.1 per cent.

Viscosity of Mixed Gases

Graham, in about 1845, while experimenting on the motion of gases, encountered the fact that by mixing a little hydrogen with carbon dioxide, the mixture can be rendered more viscous than the carbon dioxide, although the hydrogen is less viscous than it.

The condition impressed Graham so strongly that he made a large number of experiments on the transpiration of mixed gases through capillary tubes, with the result that, if t_1 is the time of transpiration of a gas, A, under certain conditions as to pressure and temperature, and t_2 the time for a gas B under the same conditions, then for a mixture of n_1 volumes of A with n_2 volumes of B the time, t, is in most cases given with considerable accuracy by the empirical formula.

$$(n_1 + n_2)\ t = n_1\ t_1 + n_2\ t_2$$

but when hydrogen is one of the ingredients, the formula fails entirely to represent the facts. As the viscosity is proportional to the time of transpiration, a similar empirical formula holds for the viscosity of most mixtures, but fails for those containing hydrogen.

Maxwell noted these facts and mentions that while hydrogen is only half as viscous as air, a mixture of equal volumes of hydrogen and air is $\frac{15}{16}$ as viscous as air.

Many attempts have been made to mix different refrigerants. Such attempts have been failures, chiefly because no stable substance resulted from such mixtures.

TABLE 8—VISCOSITY (N) OF AIR

TEMP. C.	TEMP. F.	VISCOSITY C. G. S.	VISCOSITY ENGLISH	AUTHORITY
15	59.00	1807	121.40	Landolt-Bornstein—Breitenbach
.....	.....	1850	124.30	Landolt-Bornstein—Puluj
.....	.....	1850	124.30	Landolt-Bornstein—Rossander
.....	.....	1840	123.60	Landolt-Bornstein—Warburg
15.3	59.54	1812	121.70	Landolt-Bornstein—K. Schmitt
15.9	59.72	1803	121.20	Landolt-Bornstein—Rankine
16.2	61.16	1807	121.40	Landolt-Bornstein—Kopsch
17.8	64.04	1828	122.80	Landolt-Bornstein—K. Schmitt
18.0	64.40	1911.4	128.50	Landolt-Bornstein—G. Zemplen
19.5	67.10	1831.0	123.00	Landolt-Bornstein—Tanzler
19.83	67.69	1819.6	122.25	Landolt-Bornstein—Gille
20	68	1980.0	133.00	Landolt-Bornstein—Maxwell
.....	.....	1917.0	128.80	Landolt-Bornstein—Puluj
20.27	68.486	1923.2	129.20	Landolt-Bornstein—Zemplen
20.72	69.296	1869.7	125.50	Landolt-Bornstein—Reynolds
23.00	73.80	1825.9	122.65	Landolt-Bornstein—Markwell
24.20	75.56	1852.0	124.50	Landolt-Bornstein—W. J. Fisher
25.70	78.26	1890.0	127.00	Landolt-Bornstein—Warburg
29.10	84.38	1973.0	132.60	Landolt-Bornstein—Pedersen
41.80	107.24	1956.0	131.50	Landolt-Bornstein—Puluj
61.7	153.06	2036.0	136.75	Landolt-Bornstein—Puluj
99.9	211.10	2218.0	149.00	Landolt-Bornstein—Schierloh
182.9	361.22	2571.0	172.80	Landolt-Bornstein—Schultze
197.3	387.14	2538.0	170.50	Landolt-Bornstein—Obermayer
220.2	428.36	2735.0	183.70	Landolt-Bornstein—Fisher
272.4	532.32	2840.0	190.80	Landolt-Bornstein—Obermayer
302.0	575.60	2993.0	201.20	Landolt-Bornstein—Breitenbach
340.0	644.00	3040.0	204.20	Landolt-Bornstein—Obermayer
481.7	799.06	3519.0	236.40	Landolt-Bornstein—Fisher
498.0	928.40	3551.0	238.70	Landolt-Bornstein—Fisher
501.2	934.16	3606.0	242.20	Landolt-Bornstein—Fisher

C. G. S. units in this table are in Centipoises $\times 10^{-7}$. English units are in $\frac{\text{Lb.}}{\text{Ft.} \times \text{Sec.}} \times 10^{-7}$.

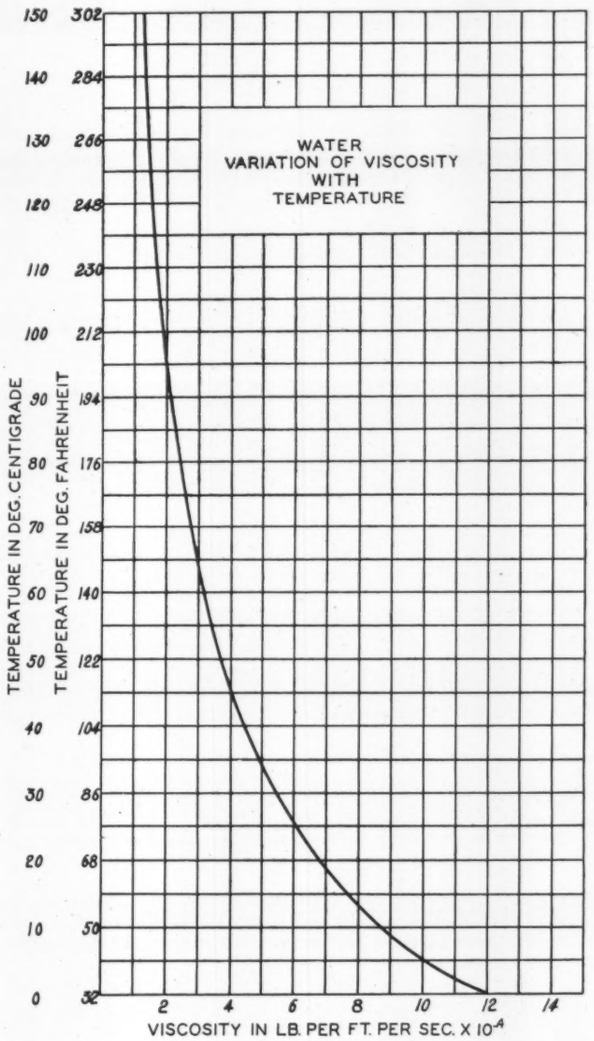
Discussion

The tables presented herewith are a collection of all the data available relative to the viscosity of several refrigerants. The substances listed in these tables are by no means the only ones used for refrigerants. An attempt was made to include several other refrigerants, such as propane, iso-butane, etc., but no values of viscosity could be found for any of them.

An attempt was also made to include dichloroethylene[3] ($C_2\ H_2\ Cl_2$) among the graphs, but was omitted because of insufficient data. Symmetrical dichloroethylene

[3] The authors are indebted to Mr. R. W. Waterfill for calling their attention to the information regarding dichloroethylene ($C_2\ H_2\ Cl_2$).

occurs in the trans-isomeric and the cis-isomeric form. These are usually produced as a mixture and are never completely separated. Dichlorethylene which is used as a refrigerant is usually one of the refined isomerics.



Herz and Rathman[4] record the value of viscosity in the C. G. S. Units at 25 C as .003901 for the trans-isomeric form and .004553 for the cis-isomeric form.

A new refrigerant has just been announced by Thomas Midgeley Jr. and Dr. A. L. Henne. It is known as dichlorodifluoromethane[5] ($C\ Cl_2\ F_2$). Mr. J. B. Churchill suggests the organic fluorine compounds as favorable possibilities for refrigerants. The question arises in the authors' minds, "Will the physical properties, such as viscosity of these new refrigerants, be such as to warrant their use commercially, because of the relation between viscosity and flow?"

Conclusions

I. The viscosity of each of the refrigerants studied behaves the same, in that it increases with the temperature and is independent of the pressure.

II. There is much more need for greater study concerning the viscosity of refrigerants.

III. The viscosity of all refrigerants should receive more attention because their viscosities may be such that if studied more carefully it might be determined which could be circulated and used more efficiently from a flow view-point.

[4] See bibliography.
[5] Division of Industrial and Engineering Chemistry of the *American Chemical Society*, May 1, 1930.

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Drop in Head for Water before Flashing

The table below gives the drop in head which is theoretically possible before flashing occurs with water at different temperatures.

Temp. of water F	Permissible drop in head in feet
212	0
200	7.2
195	9.9
190	12.4
185	14.5
180	16.6

These are maximum figures and in practice a considerable margin must be allowed. On the other hand, they are based on the assumption that the water is standing under merely atmospheric pressure. If the pressure were greater than this, then clearly the permissible drop is greater.

An Air Conditioning Engineer Builds a Home

—and Dreams About Other Homes of the Future

By Esten Bolling

MORE than fifteen years ago I decided that Air Conditioning was to be my lifework—because, it seemed to me, this new and potential science provided the means to serve humankind in the greatest measure vouchsafed unto me.

For these fifteen odd years I have pursued this bent, finding an ever-increasing interest and an ever-increasing field.

Today scientific Air Conditioning has come into its own, not only in industrial and in public buildings, but in the home itself.

There are available devices which afford to the modern home all the delights of absolutely automatic heat control plus equal and coincidental regulation of humidity plus, further, completely effective air filtration or cleansing. The manufacturers of such machines have achieved over-all heating efficiency and they promise—indeed have experimentally achieved—an auxiliary equipment which will afford economical summer *cooling* and *de*humidification, wrought by the same apparatus, aided by a refrigerating unit.

It may be interesting to digress momentarily to point out that the cooling—i.e., summer conditioning—of the average eight-room house will require approximately fifteen tons of refrigeration. At present the average modern household has a mechanical refrigerator of about one-tenth ton capacity! Thus the era of mechanically *cooled* homes will utilize in a most "every-day" manner, something like *one hundred and fifty times* the mechanical refrigeration capacity at present employed. And this use of mechanical refrigeration will be regarded as a normal operating expense, just as winter *heating* is now regarded, and, interestingly, this summer *cooling* and *de*humidifying cost will not materially exceed the present cost of winter heating and humidification. (Of course it goes without saying that we are considering winter heating *plus* proper humidification, just as we are considering summer cooling, *plus de*humidification, the one being essential to the other.)

The building of our own home has, of course, been our principal ambition for many years and we have studied and planned during all those years that it might be, though necessarily modest, convenient, livable and comfortable—above all permanent and inexpensive to maintain. Of course, from the beginning, we planned air conditioning since we live daily in its "atmosphere," so to speak, and we could not be happy without it, being too keenly conscious of its essentiality.

Another basic consideration was location. We wanted to get away from the city as far as practicable, and we wanted to be near water affording swimming and boating. We found what we consider an ideal location in Mountain Lakes, N. J., just thirty-five miles from New York City Hall, with fine motor roads and good train service, soon to be electrified. Mountain Lake itself is some four thousand feet long and covers about one hundred acres. There are five other major and five smaller lakes in the Borough. The altitude averages six hundred feet, rising gently from New York's sea-level.

We feel that we are but the vanguard of those who will, in increasing numbers, abandon our congested cities, taking both work and living to the open countryside, linked to the city, as effectively as needful, by good roads and the telephone.

In the May *Forum* Stuart Chase says: "Electric urban traction eats up thirteen per cent of all power generated in the nation. Most of it goes to pumping people back and forth from places where they would rather not live to places where they would rather not work."

Since my office is in my home we have done our infinitesimal bit to relieve urban congestion!

The plans we finally developed specified an eight-room house about thirty feet by fifty feet with a detached two-car garage, twenty-two feet by twenty feet. First floor:

living room, fourteen feet by twenty-five feet; sun room, eight feet by eighteen feet six inches; dining room, fourteen feet by fourteen feet six inches; kitchen, fourteen feet by fourteen feet six inches; maid's room and bath. Second floor: Master's bed room, fourteen feet by fourteen feet three inches, with detached bath; guest bed room, twelve feet by sixteen feet six inches, with attached bath; office, ten feet by twelve feet two inches, with storage room, ten feet by eleven feet.

General construction is cement stucco on metal with stained and oiled cypress trim, gypsum plaster on metal for all inside walls and ceilings except the bed rooms, which are papered. Andrew Lenart, East Orange, was the general contractor.

After much argument I prevailed upon Mrs. Bolling to use cork linoleum throughout the first floor, except the living room. I've always contended that a dining room, especially, is no place for a rug. Everyone agrees, now that it has been done.

Then, before we arrive at the real point of this story, may I, in my enthusiasm, insert a few words regarding some of the other comfort and efficiency features of our little house? Eight telephone stations, with buzzer calls, are built in. All but the main station in the office are equipped with plug jacks and two portable handsets enable one to talk either within, to any other station, or outside, from nearly any position. One of the plugs, Oh! joy of joys, is in the bath, reachable from any position, shower or elsewhere.

The telephone company cooperated effectively and eagerly, making the installation exactly as desired, and the cost was quite negligible. Home builders should ascertain the remarkable cooperation the company is ready and willing to extend.

In the living room, instead of a mere fireplace, we installed a most modern and effective successor to the old-fashioned masonry fire place which might or might not draw well and which shot most of the heat up the chimney. By means of an outer steel jacket enclosing the inner steel walls, air is induced to enter grilles communicating with lower openings to the space between the heated inner walls and return walls, to circulate over the to the room through grilles connected to upper openings. This installation is so effective that a normal fire will, in cool weather (50 deg. say) heat the entire house, very much as a "pipeless furnace" operates. Thus to the joy of the open fire has been added really efficient heating. Of course you can go wild on the grilles, if you like, or you can merely leave openings in the brickwork. I happen to have a friend by the name of William H. Pries, in Newark, who is an old-time artisan in wrought iron.

A Corner of the Living Room. The Telephone Station in the Front Hall Is Provided With a Key For External or Internal Communication and With Buzzers for Internal Signalling

Beside the hearth, under the wood basket in the picture, is a trap door, beneath which, at present, is a shelf, and beneath this is the woodpile. Firewood placed on the shelf is readily reachable with the tongs and all the fuss and bother of trailing it through the house is avoided. When I can, I am going to rig a dummy rising into a bottomless woodbox over the opening.

One of the photographs shows the window arrangement, with a hung (on carriers, not hinged) transom above regular double-hung sash. This gives very high windows, low enough for unobstructed view when seated, and the transoms afford effective ventilation despite rain or storm. This is a real convenience in the bed rooms at all times, and elsewhere in the "between-seasons," Spring or Fall, when the outdoor weather is fine enough to make the operation of the air conditioning system unnecessary.

Insulation and Weatherstripping Heat Loss

The heat-loss is fairly high despite one inch of insulation on all outer walls and two inches over top ceilings, on account of the unusually large glass area. We calculated the loss as 94,000 Btu per hour at zero F. The cubical content is about fifteen thousand cubic feet and we provided for a minimum air change of fifteen minutes and a maximum of seven and one-half minutes. This is more air volume than is required for heating, but I wanted to have an experimental leeway, especially for cooling.

All outer doors and windows (including transoms) are metal stripped and the inner doors from the bed rooms are also stripped, since they become, in effect, outer doors when windows are opened at night and would seriously

impair operation of the system if not stripped. In fact, a surprising economy can be effected by this simple procedure in most any house, regardless of the heating equipment.

The Air Conditioning System

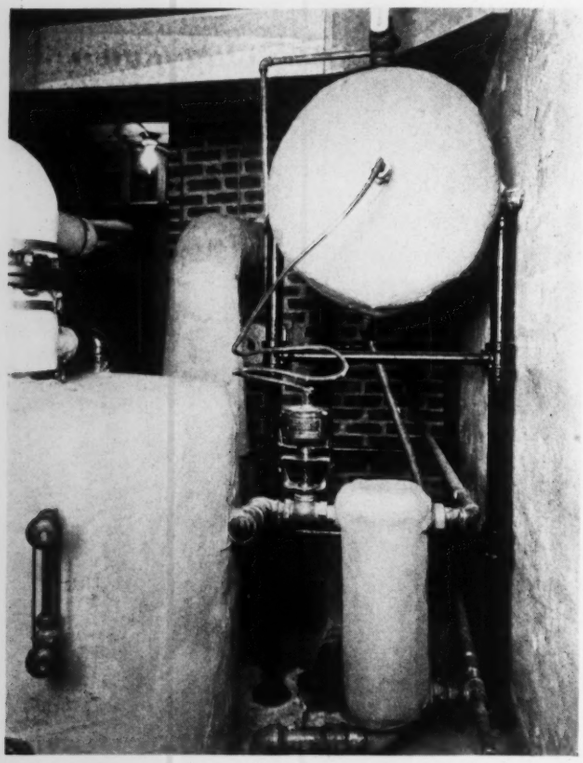
Since no gas fuel is available in our locality everything is electrical. We devised an oil-fired system and what has proved a highly economical and satisfactory means of controlling it automatically, both winter and summer.

An electrically ignited oil burner in a copper-steel boiler comprises the steam plant. Since the system is wholly automatic—inviting negligence—we installed a boiler water feeder and, for final safety, a pressure and low water cut-out. The boiler plant thus requires no attention whatever and is proof against the failure of any part of the system.

One line from the boiler feeds wall radiation in the garage, through tight ten-inch tiles, which also carry hot and cold water pipes, thus avoiding freezing.

A three-inch line from the boiler feeds three 6-tube, 2-row, 3′-0″ units of fan system heating surface hung in a pipe rack at the ceiling, as shown in the photograph. The closed circuit gravity system is used with quick-vent air valves and vacuum-breakers to prevent possibility of water-hammer under any conditions, as when starting cold after long standby.

Just beyond the fan system heating surface and below it is a copper tank in which is an "S" coil of tubing fed from the same steam main as the units. The level of water in this tank is maintained by an adjustable float valve connected outside the tank. This is the humidifying provision and once the proper water level, i.e., degree of submergence of the heat-surface, is determined for a given condition, the device is thereafter inherently automatic, since the amount of water evaporated will correspond to the heat load as the controls impose this upon the units. This method has proved entirely satisfactory and uniform.



A View Showing the Horizontal Copper Hot Water Storage Tank, Hot Water Heater With Regulator That Prevents Excessive Winter Water Temperatures. Just Behind the Lamp in the Upper Left Hand Corner May Be Seen the Firewood Shelf Beneath the Living Room Trap Door

The fan is driven by a belt-connected special ½-hp. two-speed, single phase motor, the starting and speed control units being mounted on an attached steel panel.

The photographs afford an idea of the carefully designed duct system, installed by John Heyrich of Montclair, N. J. Air is distributed to each room through one or more wall outlets located two inches above the baseboard, so arranged that air is deflected downward or upward to avoid what might be a noticeable draft if the delivery were horizontal.

In the bed rooms, single leaf dampers are provided for cut-off at night. The air delivery is *regulated* by duct dampers, with set screws, in the cellar. Hence the outlet damper is used solely to open or close the outlet. The bed rooms are provided with an extra outlet of large capacity which affords rapid heating upon arising, In fact the *air* in the bed rooms is comfortable two or three minutes after the windows are closed and the outlets opened, although the walls and objects in the room may not reach the normal 68 degrees (*ample* with proper humidity) for some time. This rapid provision of warm moist *air,* upon arising, is a boon indeed, especially for people who, like ourselves, open bed rooms fully at night, regardless of outdoor winter conditions.

About eighty per cent (in very cold weather, less in milder) of the air supplied is recirculated through floor grilles, one in the upper hall, one in the lower hall, one in the living room and one in the dining room. The twenty per cent or more of outdoor air is admitted through a screened copper hood, shown in one of the photos, and with the recirculated air is passed through air filters before entering the fan. The filter box is directly beneath the fan system heating surface and a removable leaf provides easy access for cleaning or replacement.

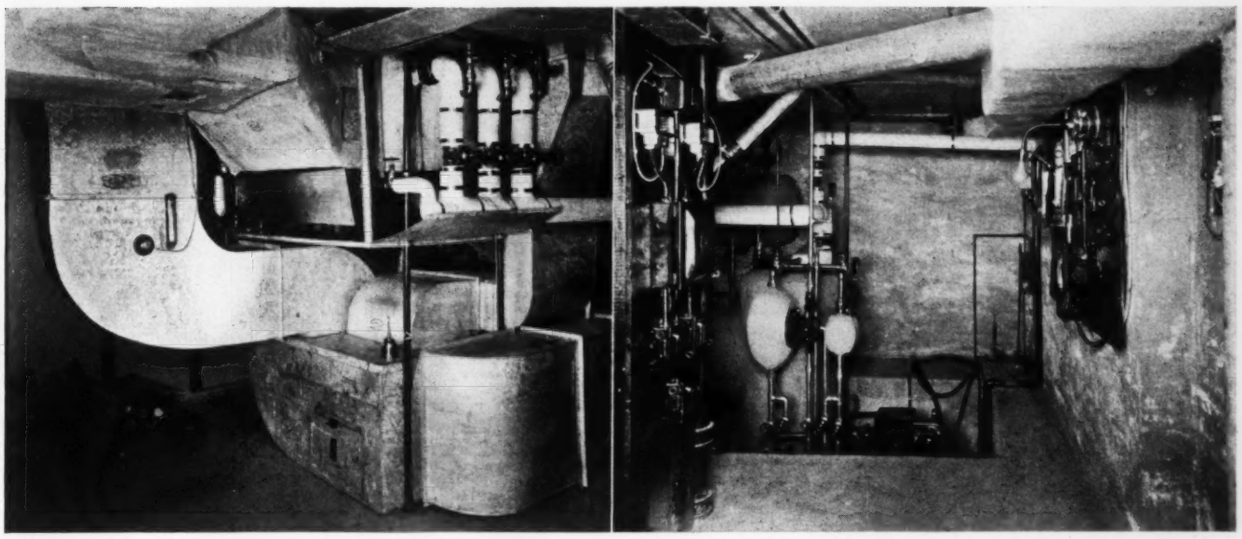
The twenty per cent outdoor air added to the circulation is removed by exfiltration (though this is small because of good stripping and tight construction) and by exhaust through the living room fireplace chimney.

There is no noticeable air motion anywhere in the house, yet the conditions are uniform everywhere within a degree, and this is true regardless of wind direction or velocity, though the very large glass area in the guest room has occasionally permitted the sun-effect to *raise* the temperature 2 degrees, especially when window shades are improperly adjusted.

Winter Control

A hygroswitch (mercury-tube) on the boiler maintains, independently, a boiler water temperature of not less than 185 F, so that the boiler is always ready to steam quickly. This, coupled with the fast-steaming characteristic of the boiler, enables us to deliver steam to the heat surface within two minutes after the burner starts, even if there is no steam in the system.

A thermostat in the dining room, operating through a relay on account of the ½-hp. fan motor, controls the



THE COMPLETE AIR CONDITIONING SYSTEM, SHOWING THE OIL-FIRED STEEL BOILER WITH AUTOMATIC WATER-FEED, LOW WATER AND EXCESS PRESSURE CUT-OUT, THE HEAT SURFACE (VALVED FOR STEAM IN WINTER AND COLD WATER IN SUMMER) THE MAIN SUPPLY AND THE RETURN DUCTS, AIR FILTER BOX, ACCESS DOORS AND CONDENSATION DRIP PANS. THE SYSTEM ELECTRICAL CONTROL PANEL IS SEEN IN THE CENTER, AND THE HOUSEHOLD ELECTRICAL PANEL IS ON THE RIGHT WALL, WITH SWITCH AND METER FOR AIR CONDITIONING SYSTEM

burner and through a secondary control in series with this instrument, controls the fan also. However, the fan circuit is complete only when the secondary instrument closes. The thermostatic element of this instrument is located in the main air duct directly beyond the heat surface (the instrument itself and all other controls and switches pertaining to the air conditioning system being mounted on the auxiliary panel board).

This secondary instrument closes, and starts the fan, only when actuated by radiant heat from the heat surface and will remain closed, i.e., continue to operate the fan, only when there is sufficient steam in the heat surface to *maintain* a duct temperature of at least 120 degrees. Hence there is never possibility of drafts, since this effect is imperceptible above this temperature.

Thus the system operates as follows: When the dining room thermostat closes upon fall in temperature the oil burner starts. If the standby interval, as in very cold weather, has been so short that there is heat enough in the heat surface to keep the secondary instrument closed, then the fan also starts, but will continue to run only if the air delivery temperature remains above 120 F. If the standby has been of some duration, as in mild weather, then the secondary instrument will delay the fan until sufficient steam is present to hold the required duct temperature of 120 F. In either case, the fan circuit also passing through the room thermostat relay, both burner and fan stop as soon as the room thermostat opens. This simple system has proved entirely effective and satisfactory. It has not been necessary to make any readjustment of the system since it was placed in operation in December last. Nor was it necessary to attend the system in any other way, even lubrication (fan and fan motor have grease-packed ball and roller bearings, respectively) until recently, when we cleaned the boiler and looked over the burner in order to determine their condition. Neither needed the inspection and would undoubtedly have operated satisfactorily for an indefinite period.

Thus we have achieved, with oil, trouble-free, automatic and satisfactory conditioning. It all gets back to Btu's *and* the efficiency with which the fuel value, so expressed, can be utilized. We buy oil of 142,320 Btu per gallon at 6½c per gallon or 21,900 Btu's for one cent. From my observations our own installation (since installation of draft control) affords an efficiency of about 70 per cent from fuel to steam, accounting for all losses. Seventy per cent of 21,900 gives 15,330 *effective* Btu's per one cent, oil. To the cost of oil must be added the cost for electricity used to operate the oil burner motor. This is so nearly negligible, about $2.50 per month at our rates, that it may be ignored. No one has ever entered our house who knew, without asking, whether we use coal, gas or oil.

Let me interject here an interesting commentary. The boiler is, as you will have noted from the illustrations, in a pit 30 inches deep to afford proper drainage fall from the heat surface. Hence, the stack height is somewhat greater than usual, augmented by the fact that our chimney rises through the center of the house to a point two or three feet above the highest ridge. This gave us an excessive draft, especially when wind was fast, a common phenomenon in this locality. By installing an adjustable, balanced leaf damper, at the bottom of the stack (through the clean-out door in fact) the oil consumption was decreased materially. I regret that I am unable to tell, now, exactly what economy was effected, since I've been too busy to observe closely, but I should say, conservatively, that the installation of this device is saving at least one-fourth, if not one-third, of our oil consumption. By relieving the "pull" on the boiler, it affords much more rapid steaming, less fuel consumption and materially reduces the stack temperature as indicated in the stack connection between the boiler and the stack itself, *above* the device. Before its installation the stack temperature exceeded 500 deg. on windy days. Since its installation the stack temperature rarely exceeds 400 deg. and usually is about 350, an unusually

low temperature with such pressure-type oil burners.

To conclude the winter (i.e., *heating*) discussion let me say that our maximum cost per month, this year, was $36.50, oil measured by gage and electricity by a separate inside meter which shows on the main panel board. (House service meter is located outdoors in service court between the house and the garage.)

And now the question of day and night control. For years, I have advocated constant (no night reduction) control. This winter I have changed my mind. I still think that with any other system but ours (or a similar gas-fired system) it is more economical to maintain normal temperature (presuming adequate weatherstripping, including inner bedroom doors) day and night, than to reduce night temperature and restore normal temperature in the morning. With our system, however, the night loss is so little and the morning restoration of temperature is so rapid that we have found it more economical to employ a timed thermostat, reduce the night temperature from 68 to 60 at midnight, and restore it to 68 at 7:00 a. m. We have also found that even in extremely cold weather the house will hold its night temperature of 60 without calling upon the heating system (though the boiler hygroswitch may operate) throughout the night. This is important to us because we are so isolated that the bark of a dog or the crow of a distant cock is a *noise*, and, in the quiet night, one *can* hear the starting control of the fan as it snaps into running position. The fan and motor are cork-isolated, and the fan inlet and the discharge are canvas-connected, yet there is a slight control and electrical noise, upon starting, which is audible in the dead stillness of the country night, though it would be lost in a more congested community.

Interior Air Circulation

As we have pointed out, about 80 per cent of the conditioned air is refiltered and returned, in very cold weather. The bedrooms are weatherstripped to avoid interference at night. But there remained two other rooms—the office, and the detached master bath—which required air circulation during the day when their doors might be closed. In these doors we installed louvres with a lever control permitting complete closure, any degree of opening or full opening. They pass little or no light, surprisingly little sound, and foil the insertion of so much as a sheet of paper, while affording about 50 per cent free area for air circulation.

In the office door, ordinarily closed, two louvres are installed. The upper one is used in summer (cooled air falls), the lower one in winter (heated air rises). The operation has been entirely satisfactory, and I think you will agree (from the illustration) that the decorative value does not impair appearances.

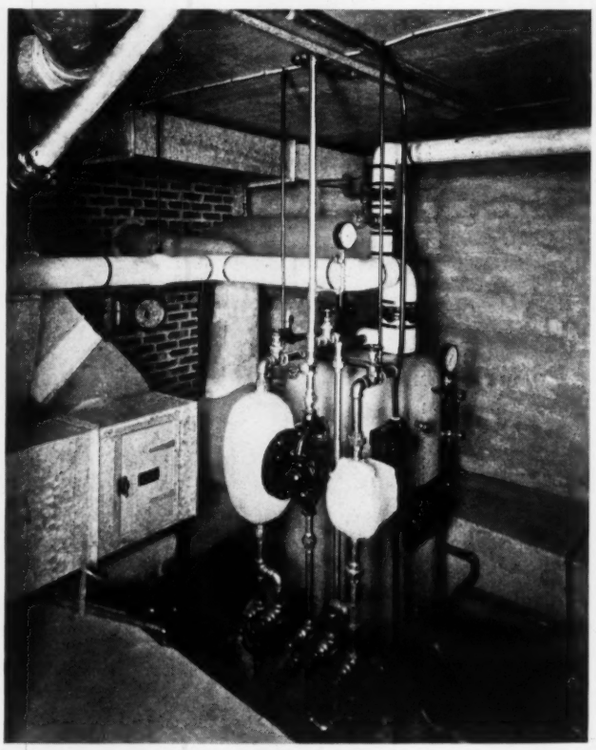
I'd like to record, here, that the plumbing and steamfitting, an unusual job for a "domestic" organization, were carried out most satisfactorily by William J. Wheatley of East Orange, N. J., who took a keen personal interest and supervised the job himself.

Summer Cooling and Dehumidification

Of course every "constant reader" of HEATING, PIPING AND AIR CONDITIONING knows that summer cooling, mere temperature reduction, is but part of summer health and comfort. The other is *de*humidification. "It ain't the heat, it's the humidity," as the old darkey remarked. To accomplish dehumidification, the temperature to which the air must be cooled must, of course, correspond to a dew-point temperature which will condense from it sufficient moisture so that its final relative humidity, at the maintained temperature, will be low enough to insure comfort, as well as to guarantee health. This dew-point temperature varies with outdoor conditions, but, for a fair example, should not greatly exceed 50 degrees under any outdoor conditions, and should usually be much lower.

Therefore the summer conditioning must contemplate a dew-point temperature of something like 50 and, thus, a cooling-medium temperature sufficiently less than this that the resulting temperature to which the air is cooled may not exceed the allowable 50 deg. Since, with a heat-interchange system such as ours, or similar, it is difficult to cool closer than from six to eight degrees of the cooling water temperature, the temperature of the available cooling water must not much exceed 42 to 44 deg. It happens that where we are located our water supply is from deep wells and does not much exceed these temperatures, even during the hottest summer weather. Hence, we have arranged to utilize this water for cooling, for the time being. (Eventually we plan to sink our own well or utilize mechanical refrigeration.)

A glance at one of the illustrations will show that the heat-surface is so piped that the steam may be valved off and the cold, house-supply water taken through it for summer conditioning. It may be interesting to note



CLOSE-UP OF BOILER, BURNER, WATER FEED, LOW WATER AND PRESSURE CUT-OUT, DRAFT REGULATOR, AND FAN INLET ACCESS DOOR. NOTE THAT EVEN STACK CONNECTION IS INSULATED

that the pressure at the point where our water supply enters the house is from 175 to 185 pounds per square inch. (This is, of course, reduced for house supply, but piped at full pressure to the heat-surface.) The piping is so arranged that the effluent water from the coils, now acting as *cooling* rather than heating surface, may be sprayed over the roof, to take advantage of the wet-bulb depression, used for sprinkling, or sent to the sewer, as desired. (If the summer conforms to the last two weeks it will be used for sprinkling the lawn (an acre) and the house garden.) (An additional half acre has not been landscaped simply because we couldn't afford it!)

The shift from winter to summer control is made by throwing the four-pole, double-throw switch on the control panel-board, from lower to upper position.

This cuts out the dining room thermostat and places in circuit the return duct thermostat. This instrument is so arranged that the fan is started whenever the temperature *rises* above its setting, which, normally, is 78 F. There is, at the present moment, no automatic control of the cooling water flow, though connections for this are provided and will be installed as soon as this summer's experience has afforded the necessary data. During a recent untimely hot-spell when outdoor temperatures exceeded 80 F, were, in fact, momentarily above 90 F, we found that we could achieve any desirable degree of cooling by manual adjustment of the water-flow.

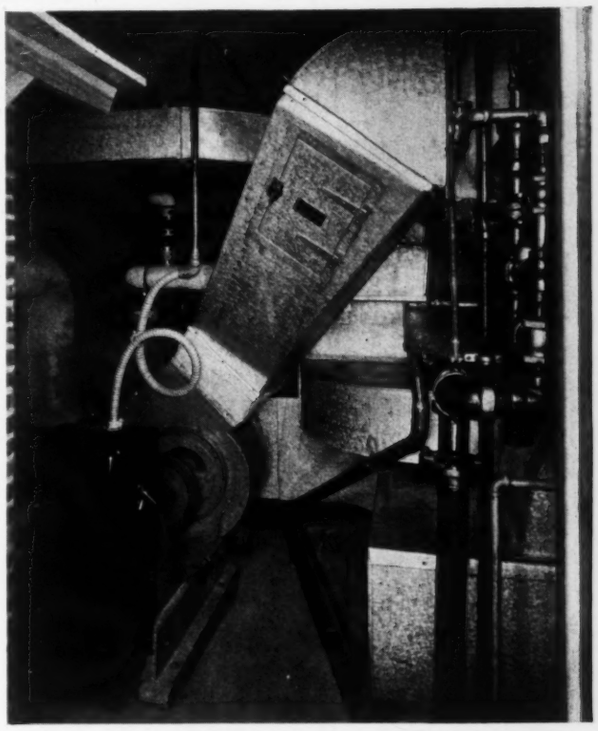
Summer Control

As pointed out, the movement of a single 4-pole, double-throw switch shifts from winter to summer control (except cooling water flow, at present). Under summer control the return-duct temperature actuates the fan (while the flow of cooling water is regulated by hand).

As previously mentioned, we shall study the operation of this method through the ensuing summer. Later we may find that it will pay to sink our own well, for cooling, sprinkling and such purposes, or to install one of the types of mechanical refrigeration.

It is interesting to note that, during a recent hot-spell, the opening of doors and windows, during the day, was irresistible, although, thinking the untimely conditions ephemeral, we did not shift over to summer control. Hence the temperature inside the house approximated that outdoors at sunset. As the "coolth of the evening" developed (i.e., when the sun-effect disappeared), by utilization of the fan, the interior of the house was quickly brought down to the outdoor temperature, though visits to other nearby houses showed them overheated for hours after sundown, because there was no provision for the expulsion of the indoor air, unless intractable Nature happened to provide an effective breeze.

Ere this summer yields to fall we expect, also, to develop some interesting information as to the value of mere controlled fan system air *circulation,* unaided by artificial cooling. I think the effective use of such circulation has possibilities far exceeding our present conceptions. Especially in conjunction with efficient insulation when the house is closed, at dawn, against the usually higher day temperatures. At any rate, we shall, with much glee, undertake to see—reporting any interesting results.



THE FAN AND MOTOR UNIT, WITH ACCESS DOOR AHEAD OF HEATING SURFACE

Auxiliary Ventilation

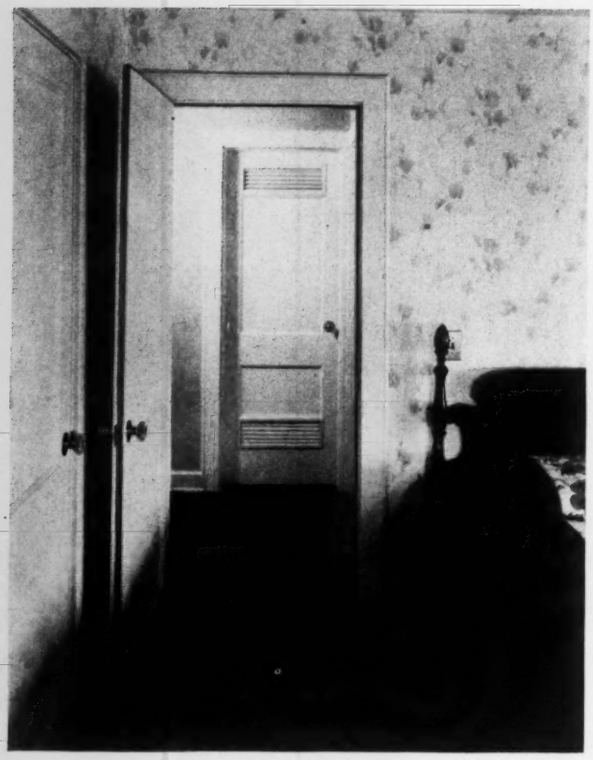
Auxiliary exhaust fans are installed in the kitchen and the cellar play room. The first, ceiling mounted and blowing through a self-closing shutter, exhausts about 10 per cent more air than is introduced for conditioning, preventing kitchen odors from entering the recirculating system. The second exhausts tobacco smoke and body heat from augmented assemblies busily engaged in various forms of indoor sports,—Ping Pong, for instance, being an extraordinarily active "inside" game!

And, here, another comment which seems interesting to us. The laundry is located in that half of the cellar which houses the conditioning system. By closing this off from the adjacent play room there is sufficient circulation of warm, filtered air (the higher temperature reducing the relative humidity) to accomplish extremely rapid drying of "the wash," a boon in winter and on other rainy days. The normal duct leakage (no special outlet being provided, though it was contemplated and found unnecessary) furnishes the "supply" and the sensitive draft adjustor provides the "exhaust." It works like a charm.

And, of course, we have not yet discovered all the things the flexible, controllable system can accomplish, though we are learning day by day. The big thing—the fascinating thing—is that we have ready means of controlling—heating, cooling, humidifying, dehumidifying, *directing* and *moving,* that basically important commodity, the air in which we live—the very breath of life!

Hot Water

Since we have no gas for summer hot water, we rigged to heat summer hot water by oil. When the



Looking From the Master's Bed Room Into the Upper Hall, Showing Weather-Stripping of Bed Room Doors and Upper and Lower Louvres in Office Door. The Upper Hall Floor Return Grille Also Shows

4-pole shift switch is thrown to summer position the boiler hygroswitch is circuited to hold the boiler water temperature at 185 F, just as it does in winter. An oversized indirect heater then keeps the *horizontal* copper tank, of ample capacity, *full* of water at 160 F (a vertical tank, as ordinary, would be, usually, only *half* full), this temperature being controlled by means of a self-contained regulator, located in a circulating leg of the heater. The oversize heater is so effective that (from present brief experience) the burner will operate normally but three or four times per day for very short periods (apparently less than ten minutes). Of course the heater and the storage tank are effectively insulated. The recent brief 16-day "heat-spell" bore out the expectancy of infrequent and short burner operation, but the fuel consumption was so small that it could not be measured on the gage. It appears—and this has been substantiated by four or five other installations with which I am familiar—that the cost of summer hot water, by this method, is so small that an entire summer must be observed in order to determine it! We'll have the dope by September; but it may be declared *now* that the cost will prove astonishingly little, and the system is care-free and automatic.

Observation Facilities

As might be guessed, we have provided, for our pleasure and edification, the necessary gages and instruments for careful technical observation of the system's operation.

The local electric company has co-operated interestedly and effectively, furnishing the inside recording kw.-hr. meter previously mentioned, and such other equipment and assistance as was suggested. We have recorded the house line voltage variation over a period of two weeks and have reduced this to almost nothing, despite the heavy (for a small residence) occasional demand. We have, in fact, so perfected the electrical system that the all-electric radio set (extremely sensitive) is now unaffected by any of the household electrical equipment.

Advantages of Controlled Humidity

I've written so voluminously upon this subject that enlargement here seems inept.

But it *is* interesting to point out the *obvious, impressive* advantages we have enjoyed this winter.

Cleaning and dusting have been minimized. That ordinary accumulation of "lint" which bedevils the housewife and is due primarily to the breakage of textile fibres (from rugs, drapes, clothing) due to brittle dryness, has been unknown. No furniture has warped or cracked and no bureau drawers have stuck or sagged.

Flowers, cut or potted, live luxuriantly three or four times as long as in our former steam-heated apartment and our pair of wire-haired terriers are veterinarily-certified the liveliest and healthiest in the United States.

Our own dispositions are remarkably equable,—though I dare not estimate how much this is due to Mrs. B's general charm and restraint,—and how much to air conditioning! But the air conditioning helps,—I may say without disrespect nor unappreciation!

All this, of course, treats merely of winter conditioning.

About summer?

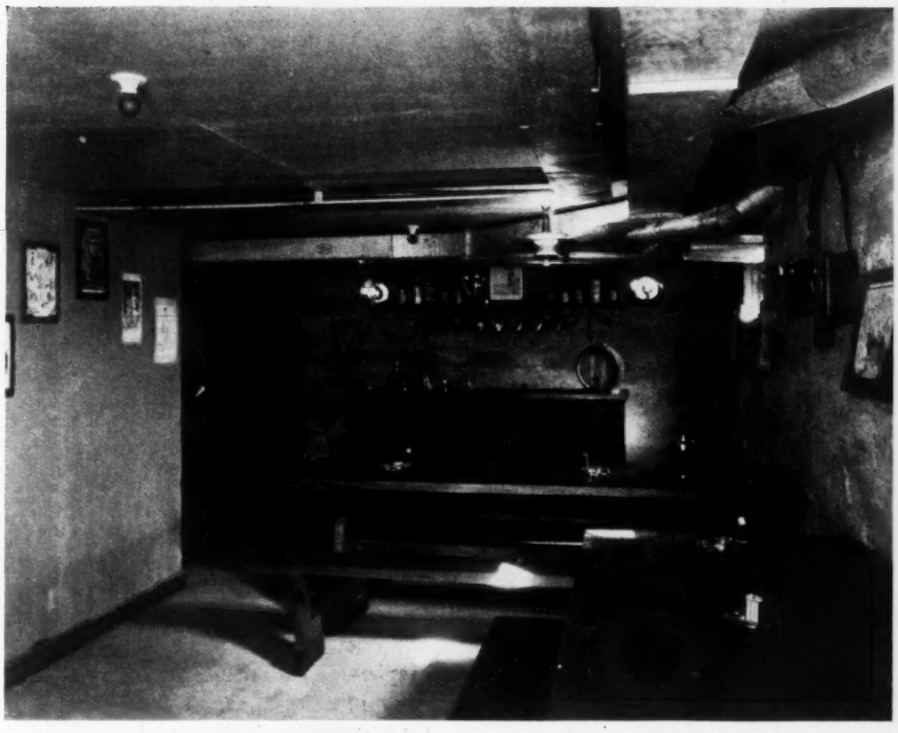
Well, nearly everyone knows that the old darkey is right. Temperature reduction is important, even desirable—but not very effective without humidity control —may be, in fact, detrimental. Thousands of people know that temperatures in excess of 90 deg., with attendant *low* humidities, as occur in some of our mid-western States, are not excessively uncomfortable. And many more thousands know that an 80 deg. day in New York, with the relative humidity at 80 per cent, well nigh surpasses human endurance. It sure "ain't the heat, but the humidity"! And since ours is an air conditioning system, and is capable of reducing the *resultant* relative humidity as well as the temperature, we can look forward to our first really comfortable, healthful, invigorated summer! Perhaps some heat-stifled reader of this would like to hear about it. If thon would, will thon let us know?

Resumé

I hardly think that our system would be practicable for general installation, though a modification of it might.

And for years I have wondered if *any individual* air conditioning system will prove *generally* practicable. Not only is there the question of initial expense, but the many matters of maintenance and intelligent operation. Some say we can so automatize operation that no owner intelligence is necessary. After fifteen crowded years I still disbelieve this!

The dream of the future, as I see it, is *centralization.* Suburban communities developed by *engineers,* rather than by realtors, in which the manifold advantages of modern science are made available by intelligent cen-



THE CELLAR PLAY ROOM, ADJOINING THE CONDITIONING PLANT, SHOWING SOME OF THE DUCT WORK, ALL DRIP-PROTECTED AND THE DRIP PANS BENEATH THE COLD WATER PIPING. THE TELEPHONE CONNECTOR PANEL AND BATTERY BOXES ARE ON THE RIGHT

tralization of facilities. I can not, in fact, comprehend why this has never been achieved. (Sometimes I think the following outpouring of my dreams may be regarded as technical heresy. Nevertheless, here goes!)

Contemplate a suburban area possessing the desirable factors of proximity, access, communication and extent. Then assume that some previsioning group of financiers, realtors, and *engineers,* undertakes to create here a really modern community, though by no means an "exclusive," "expensive" development,—one available to those of moderate means. Let the ample area (there are hundreds of exceedingly desirable "ample areas" in suburban New Jersey, and undoubtedly elsewhere) be divided into "building lots" of ample extent, not less than half acre, I should say, and let there be erected thereupon modest, but *scientifically designed* homes, so constructed that maintenance is minimized (I believe modern science can well nigh *obliterate* maintenance) that "livability" (with or without service) is maximized, that all of the "mechanical" necessities or accessories are entirely eliminated from the homes themselves and *centralized* in a community station which will provide air conditioning (heat, humidification, cleaning, and uniform air distribution in winter; cooling, *de*humidification, cleaning and uniform air distribution in summer); hot and cold water; household refrigeration; gardening and landscaping advice and assistance; selective radio (and, when available, television) service; motor car (or airplane) maintenance; school bus service, good roads and their maintenance, etc., etc., all of it tremendously more effective and permanent than any single family could afford (or would know how to achieve!) yet furnished unobtrusively and inexpensively to each household, leaving it as independent and democratized as only a very few venturesome or exceedingly wealthy families can now accomplish.

Every engineer knows the immeasurable advantages of centralization. Heating, refrigeration, radio, what-not, are, by centralization, rendered as highly efficient as the present-day, accepted, commonplace methods of centralized water, electricity or gas supply. In my opinion, one might as well, today, sink one's own well, generate one's own electricity, manufacture one's own gas, *fabricate one's own motor car or airplane,* as install one's own heating system, one's own miniature household mechanical refrigerator. The economies achieved by the great public utilities can be duplicated, very nearly, by much smaller and almost as highly efficient *community* units, though never approached by *individual* units.

This, then, is our dream.

It could be realized today. Because the engineering is developed and available. It needs only *co-ordination.*

In fact this philosophy needn't nettle anyone (neither the manufacturers of boilers, heat-surface, air conditioning equipment, refrigeration, water supply apparatus, the makers of oil burners, or gas-producers, central power apparatus, or what-not), since it is obvious that communities developed along the lines of this conception would afford a greater and much more profitable outlet for their wares than the far less efficient, *but much more competitive,* individual installations which they would supplant—or the even less profitable present-day installations represented by the tenement or apartment house, the multi-story office building, or the citified "loft."

We present our own little home as an insignificant, and yet significant step in what we hope, and believe, is the right direction, a weather vane indicating the trend, or what may soon be the trend, of modern thought.

After Your School Plans Are Made ——

ONE cannot be triter than to repeat the old saying that "there are two sides to everything, even stories," and yet there is probably no saying which is truer than this and which may be demonstrated more frequently.

So, in heating and ventilating there are at least two sides and many claim that a dodecagon is not an exaggerated figure when applied to the problems confronting the engineer, to say nothing of the contractor. All of which leads to the reason for presenting this brief article, "on the other side," the experiences of field observation as contrasted with the engineering or "inception" side.

The writer has had many opportunities to observe the results of engineering planning not only in practice, but has had, perforce, to change, correct and advise in connection with heating and ventilating plants in school buildings; all further remarks will be understood by the reader as referring only to this class of building and the contents of this paper are offered as indicating some of the things supervisors, such as the writer, are up against. It is also to be understood that to him, no responsibility for lay-out or approval attaches except as the school authorities are entitled to the advice and service of the department which he represents. In some cases, of course, flagrant violations of codes or even common sense are required to be corrected.

Closer Co-operation Between Engineer and Architect

One of the first comments it is desired to make is that one might wish for even a closer working co-operation between architects and engineers than usually exists. We have seen innumerable plans submitted for approval with heating and ventilating layouts barely sketched in and subject to change, revision and entire revamping. Later, it is frequently found that the changes to be made or the types of devices to be finally installed do not fit the spaces originally designed to hold the apparatus. Consequently there is much scheming and shifting and, too often, squeezing, in order to get the whole job included in the building properly. One cannot always blame the architect because changes are often insisted upon by the owners after the whole job has come off the boards; sometimes, and too frequently, it is a hurry-up job and insufficient time has been given over to judicious discussion and planning.

Many times it is found that architects' estimates are slovenly and are made without due care and where the bids are in it is found that the original system has to be cut and revised or changed entirely in order to have the price come within the available appropriation. As the building is often already under construction and important changes difficult to make, why *then the millstones grind the heating engineer exceedingly fine!* Even the gods could do no better! And the contractor? He is too often of the genus capra, otherwise known as "goat."

Apparatus Often Crowded

Another matter which has intruded itself upon the writer very frequently is the limited space originally given over to the heaters and auxiliary devices. Of course, at 28 to 35 cents, over-all cubic foot costs are not to be ignored, but certainly a reasonable, *well-lighted* and *cheery* space, with ample service spaces, is not asking too much and the writer has the temerity to suggest that "educational spaces" might well be somewwhat restricted, if necessary, in order to have the former come to pass. Maybe all architects are desirous of giving adequate space over to the heating and ventilating apparatus, but we are afraid that the wish in this respect is not too frequently the father of action, if one may paraphrase here. Interesting enough, it is not even always *necessary* to squeeze and skimp and yet when attention is called to the matter, "why the plans are completed and it is difficult to make changes," etc. Give the engineer and janitor, or the more recent custodian, some elbow room.

To illustrate the matter, let me show you a job taken directly off a set of plans and presented herewith. Of course it is not a million dollar job. Those usually get all the attention; however, it is quite representative of half the jobs in this class. One could not blame the engineer if he kicked like the proverbial steer or even refused to design the job within such a limited space. But it was done! Can you imagine the sheet metal job and the piping job and the tortuous path to the motor and the dinkey step ladder needed to get at the inaccessible shut-off and air valves? Space even forbade by-passing the blast coils—therefore roast or freeze. Who is to blame for such a situation? Probably no one is entirely blameless but the writer can make a mighty good guess at it—who is mostly to blame.

It follows from this that one could wish that every designer not only *had* an opportunity but *took* it, nay, be *required,* to inspect his handiwork in situa and see it work in practice. Many of his previous designs (and mistakes) would no doubt be materially changed and a much better attitude developed between architect and engineer on this basis which is surely a common ground. But experience certainly shows that this first hand observation is not generally being done by the engineer or designer.

Again a question has often arisen as to who is responsible for the supervision of the "specialties" which go to make up so much of a modern school plant. Is the heating engineer responsible for the installation of his design, the heating contractor or the architect? Yes, we know there are contracts and clauses and all that sort of thing, but in spite of all these a lot of queer

—— *It is Worth-while to*

"Check and Double-Check"

By H. W. Schmidt*

things get by. The architect is not supposed to be an engineer, at least he is not in most cases; the general superintendent is and cannot be an expert in all lines. Are the foremen of the various sub-contractors the superintendents? Are they to be held responsible?

Experience in many cases has led to the observation that the final responsibility is not at all well fixed, as shown by the squabble, and sometimes litigation, among the various parties concerned. The setting up of carefully worked out standard contracts and specifications, such as those of the *A. S. H. V. E.*, the *A. I. A.* and others, has helped some, but they are apparently not yet foolproof.

In order to clinch some of the matters presented so far, may the writer cite some "case studies"? The answers to the questions implied therein must be supplied by the reader, possibly in the light of the foregoing statements or from his own experience. It would, however, be mighty interesting to get a consensus reaction and make a list of the original alibis if such there be. Let it be understood that the writer is not criticizing anyone in particular nor any group in general—the facts must speak for themselves.

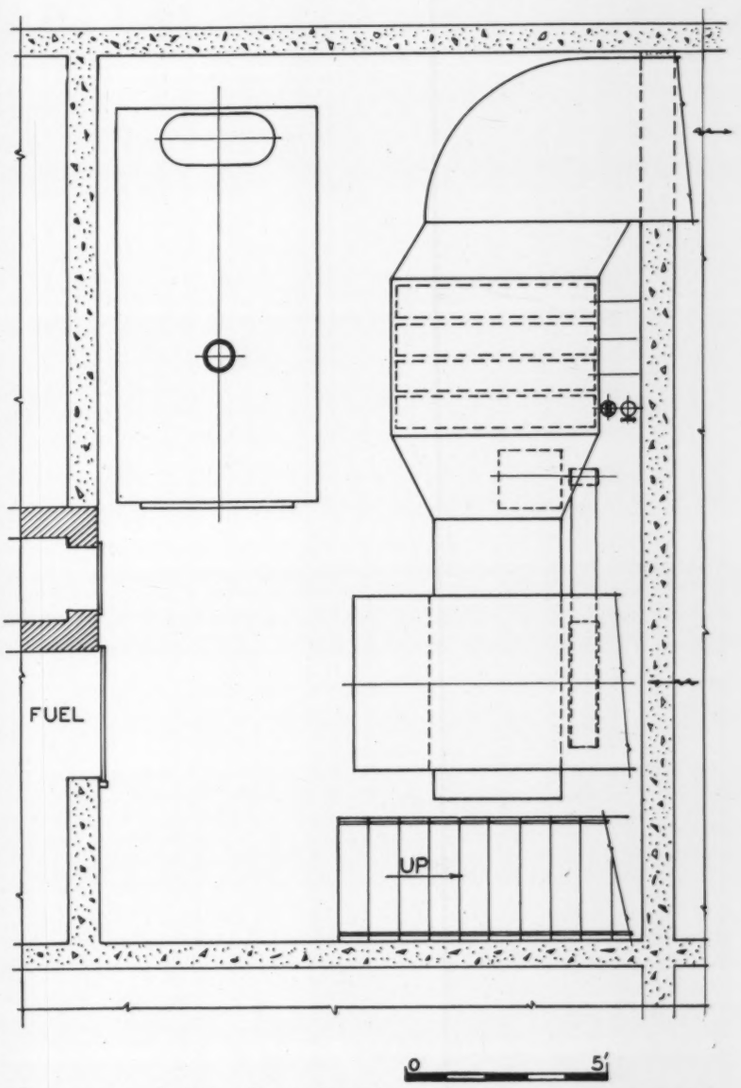
Dangers of Over-done "Economy"

School *A* has trouble in heating and ventilating a certain portion of the building. The part in question is an addition erected about eight years after the original building was built. It is about 150 feet from the old, remodeled heating plant to the center of the new heating load consisting of about 5,000 square feet e.d.r. Observation showed a vacuum system with a very small, poorly pitched return, an indifferent or rather cheap pump, poor traps where there were any, a pocketed steam main, air-locked indirect as well as direct radiation. In the morning the direct radiation was literally "convulsed" to get rid of condensation and quite a number of sections had given way under the strain.

Checking the plans showed many important variations from the original. An inferior pump had been installed, cheap radiator traps substituted; indirects had poorly-constructed air valves and were found to be short of the required radiation. The return was one size smaller than indicated and automatic temperature control was not connected to all spaces. All this, "for economy's sake," "somewhat short of money, etc.," and *changes made without consulting the designing engineer.* Who was responsible? Quien sabe? Original saving $2,100; changes and return to original plans $3,900 and not as good a plant as designed. The main steam line was pocketed due to the fact that it ran through a wooden partition and the hole for the pipe had been cut 1½ inches too low, so the pipe was bent! Almost impossible, you say. Agreed, but you can't laugh it off!

Too Little Radiation

Another split job had trouble with heating and it was found necessary to operate the indirects at full load nearly 100 per cent of the time, though the direct



FREQUENTLY, LIMITED SPACE IS GIVEN OVER TO THE HEATERS AND AUXILIARY DEVICES

* Supervisor of Buildings, Department of Public Instruction, Madison, Wisconsin.

radiation was apparently calculated to take care of about 75 per cent of the heat losses. A careful check showed that the direct radiation was 475 square feet short of that called for on the plan; five feet here, ten feet there and so forth. The shortage amounted to 14.6 per cent of the total. They are still fighting as to who pulled off that trick!

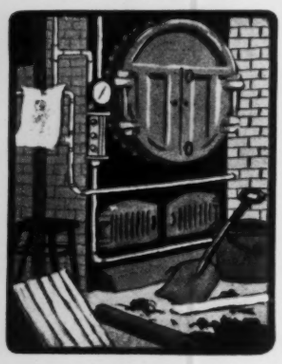
A small town job had difficulty with its recently "remodeled" steam heating and ventilating plant, a gravity indirect ventilating lay-out. "Can't heat building until 10 or 11 o'clock in the morning"; "It knocks something fierce," etc. Inspection showed a single pipe gravity return, revamped somewhat. Water hammer *was* bad; the indirects were air locked and at the time of my visit, with the outside temperature 25 F, the boiler carried 7 pounds of steam with the damper lever tied down with an old pipe fitting.

The fitter had cut his vertical supply to the indirects too long and all four coils were served by a pipe pitched towards the coils. The air valves were inside of the galvanized casing and inaccessible; the casing had to be ripped out to get at them. Five out of the eleven radiators pitched the wrong way. A two-inch horizontal supply pipe, 18 feet long, was not hung from the ceiling at all but in turn it supported a one and one-half inch supply, with, of course, the inevitable result.

The planned revamping was okey and approved, but what is one to think of the contractor's job? Here at least was a real responsibility and after a warm session with all concerned and many alibis offered, the job was properly serviced and has since proved satisfactory. But the designer never saw that job. All right, but nevertheless he had to take the brunt of the first shock until it was proven that he could not be held responsible.

Improper Placing of Coils

Some time ago I was asked to diagnose a 100 per cent blast steam job where difficulty was experienced in heating certain rooms. It was found that the lay-out was "peculiarly interesting." The main duct, directly after the indirects, was divided into two sections to serve five rooms each—the division being by means of a "splitter"! This was of 24 gauge metal, nearly five feet high and two feet wide. It vibrated beautifully, around low "C" I should say. On account of small space and improper setting of coils, the main duct was about 10 degrees off the perpendicular from the coils. This explained in part why one section of the building was always warmer than the other.



But one room was always cold. The outlet seemed to deliver the proper volume of air, but no heat. Finally the whole side of the plenum chamber was opened up and it was found that the duct casing was 6½ in. wider than the indirects were long (on one side) and the air simply by-passed at this point and went its way to room *X*. Thus the why-fore-ness, but it took hours to discover the cause. Here it was found that the designer designated the exact size of the duct, which was too wide, and also developed the splitter idea. On his part the contractor was careless in setting his coils and thus called for a bad off-setting in the first place with its attendant diverted air flow.

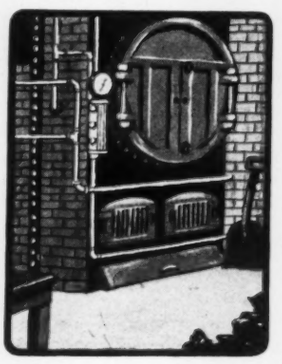
Dirt Pockets Necessary

One difficulty experienced in many jobs is the absence of dirt pockets in the return end of large pipe coils and blast heaters. Traps are found choked with dirt and scale and are often completely inoperative. Again inefficient and inadequate traps are a source of much annoyance, as well as the placement of improper check valves. Again price seems too frequently a consideration and specifications are very often ignored or changed in "minor" matters such as specialties, etc., when, as a matter of fact, these latter are usually selected because of their peculiar fitness for the place or in the system. Experience seems to indicate that careful and expert supervision is called for here.

Special Training of Operating Force Essential

One may mention an "indirect" feature which materially influences the practical working of a job, the selection of a competent engineer and staff to run the plant. In many states and localities no license or special qualification is required of an individual who is to be in charge of a heating plant. We are not speaking of the very large school systems where engineers, firemen and janitors are specially trained on the job, but of the other 75 per cent. One might wish that school authorities select their working staff with the same care that is used in selecting teachers or a superintendent and the results would be eminently more satisfactory.

It is not saying too much that the best of jobs may be very unsatisfactory in the hands of an unskilled or incompetent individual, nay, may even be ruined. To find fuel consumption varying 15 or 25 per cent after a change in operating staff is not overstating the case. No doubt many readers can subscribe to this statement at first hand. The experience that so many operators do not know their system, the amount of radiation, the kind of specialties used, the amount of fuel they burn nor the most elementary principles of thermodynamics is surely not an experience unique only in the writer's work. It appears that an educational campaign in the proper direction is most desirable, if not necessary.



In closing, there will be cited a more pleasing picture, sometimes found where some idealism, even in the objective sense of a steam heating job, exists. It was in

a small rural school which did not look the care bestowed upon its "insides." There were found splendid air conditions and a reasonable temperature, 69 degrees on a raw, cold and blustery day. The new job, a replacement, consisted of a first class low pressure boiler of ample capacity, an excellently piped vapor job including an automatic water feed of the injector type, Hartford loop, excellent trapping and venting, automatic temperature control of a simple but effective type, unit room ventilator, etc.

May there be more of such jobs, no matter what the type of system used!

Static Electricity in Industry

By Edgar S. Miller

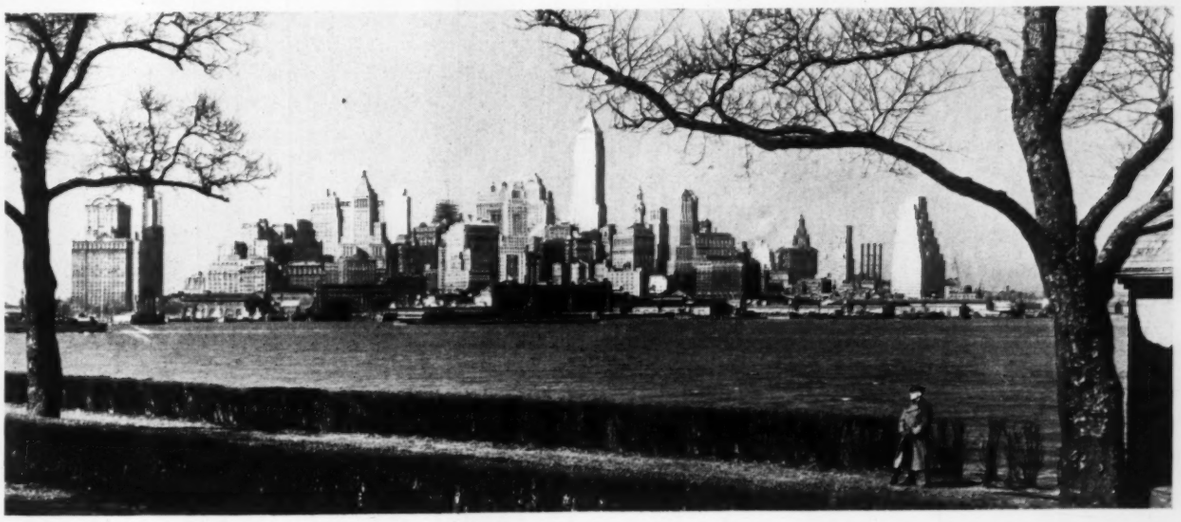
STATIC electricity, so called, was unquestionably the first recognized manifestation of that mysterious "something" now generally designated *electromagnetic force* which came to the inquiring mind of man. The very name, *electricity*, is derived from a commonplace substance whose only connection with the subtle force is no closer than that of ice to heat; and yet so impressionable is the mind of man that the word *elecktron* —amber—is the root of a far-spreading nomenclature.

Static electricity or, more properly, the behavior of an accumulation of electricity when it ceases to be static, is, as is electricity called by any name, dependent largely upon the nature of contiguous bodies. The discovery of electrical conductivity came in the early years of the eighteenth century, though, of course, at that time there was virtually no practical application made of it. Stephen Gray's experiments with "friction electricity" proved that the "fluid" could be transmitted to a distance through any substance "that could not itself be electrified." This is to say that when a connection between the body holding the static charge and a body capable of receiving the charge was made with a cord composed of "a substance that could not itself be electrified" (a good conductor) the charge refused to remain static, and passed along or through the cord to effect equilibrium.

As knowledge of the manifestations of electricity slowly increased, the condenser was recognized. Broadly speaking, all of the early apparatus used by experimenters were condensers. The Leyden jar was the first intended as such, though its function differed from that of any "friction machine" only in degree. In reality, any static charge is an accumulation of electricity, and is "condensed" only in the sense that an attenuated fluid is condensed by virtue of a closer approach of its molecules one to another.

It was Franklin who first conceived of clouds as condensers, and his lightning-rod theory was based upon the principle of gradually discharging electrical accumulation, rather than to allow the accumulation to become great enough to discharge itself violently and sometimes disastrously. Franklin, of course, spoke of "electrical matter" and "common matter," and evidently considered the charges on clouds simply as an accumulation of the "subtle fluid" upon the particles of "common matter," —water—of which the clouds were composed. But the significant point is that he contended that a large accumulation could be avoided by providing means for a gradual discharge. The same situation exists everywhere, today and always. A discharge of appreciable violence never occurs when an adequate means for an uninterrupted flow are provided.

The chief cause of static accumulations is said to be friction. It is notable that in connection with the phenomenon with which the practical man is most concerned, a necessary condition for the accumulation of static is the absence of water. If one's hair is inclined to follow the comb, a little water will quickly remedy the difficulty; if you want to draw sparks from a cat's back, don't try it when pussy has just come in out of the rain. The reasons are immaterial; the facts are important. It may be that the inhibition is due to the in-



stant permeation of an air stratum by a vapor whose enormously extended surface is able to act as a condenser of high capacity, and that there is not enough "static" to build up a high potential over so extended a field. It may be that the vapor, diffusing in the air, acts as a conductor, as did Franklin's lightning-rod, and that though the quantity of static produced in a given time may be equal to that which would cause a violent discharge, the continuous flow prevents any considerable accumulation.

A high percentage of relative humidity in the air has been suggested as a remedy for static accumulations and discharges. Under some conditions the suggestion is sound, but these conditions are such as to make the term "relative humidity" meaningless. If the *temperature* of the mixture of air and water vapor is such as to insure a high *absolute* humidity also, then the condition is effective, which is to say that it is the absolute humidity (the actual number of water molecules mixed with the oxygen, the nitrogen, etc.) that is significant.

A leather belt traveling over a pulley at high speed in a cold room will give off sparks with considerable facility. The relative humidity may be fairly high, but if the temperature is about 40 degrees it is not likely that more than two grains of moisture per cubic foot of air will be present.

The number of molecules of water mixed with the molecules of oxygen and nitrogen under such circumstances need not be even roughly estimated; it is enough to know that they are fewer by one-half than the number contained in air at 61 degrees, with the same percentage of relative humidity, and that 95-degree air with a relative humidity only about half as high must still contain almost three times the number of water molecules as does the cold air.

Such evidence as is available indicates that the significant factor in the accumulation of static electricity is the distance between the water particles contained in air. This in turn involves the number of particles present in any given space. Since, in atmospheric air under ordinary indoor conditions the water mixed with air is always in the vaporous form, a measurement of the absolute humidity of such air is a measure of its electrical conductivity. The addition or subtraction of heat will not increase or lessen the number of water particles mixed with a certain quantity of air, unless, when heat is added, there is available liquid water for vaporization, or unless, when heat is abstracted, the moisture-heat equilibrium of the mixture is disturbed. Thus, it appears probable that a variation in temperature, the absolute humidity remaining constant (which means, of course, a variation in the *percentage of relative humidity*) may be practically inconsequential, so far as the ability of the water particles to carry away "static electricity" is concerned.

The problem of the avoidance of violent static discharges, however, must also have another side. A certain pipe may be of ample size to convey, at a low velocity, the steam generated in a boiler when a given number of heat units are added to the water. Thus, under normal conditions, the accumulation of steam in the boiler would be small and the pressure but little above that of the atmosphere. But suppose the heat input were tremendously increased. The pressure would rise, and the velocity through the pipe would increase as the pressure increased. However, it is conceivable that the steam might accumulate faster than the pipe could carry it away, in which situation the restraining walls of the boiler might fail. A violent explosion, so-called, would be but a rapid restoration of equilibrium of vapor pressures, just as a "static discharge" or a bolt of lightning is such a restoration of equilibrium of "electrical pressures."

The rupture of the steam boiler might have been avoided in two ways. If the pipe had been large enough to carry away all the vapor resulting from the greatest possible input of heat, no great accumulation would have been possible; and, on the other hand, if the cause of the excessive generation had been removed, the accumulation would likewise have been held low.

In the same way, the violent discharge of static is due to an extensive accumulation, which could not exist if the means of dissipation always equalled the means of generation, either because the former is large or because the latter is small.

It is, perhaps, of little practical importance whether the *generation* of the "atmospheric electricity" which is the basis of troublesome accumulations be prevented, or whether the accumulations be inhibited by a constant removal, by means of suitable conductors. Certainly there are many situations in industry where generation is inevitable and where the use of ordinary conducting media is impracticable. It appears, however, that there is one conducting medium that can be almost universally utilized; and that is water vapor uniformly mixed with atmospheric air.

It must always be remembered that air is not nearly as mobile as is commonly believed. The atmospheric conditions obtaining in different localities within any room are variable, and cannot be brought to even approximate uniformity without the employment of mechanical means. If friction is the cause of the generation of static, the motion resulting from a disturbance of the heat status may be expected to result in a disturbance of the electrical equilibrium of contiguous particles. It is well known that steam passing through air with a high velocity will produce electrical manifestations, and it is logical to assume that the friction engendered by the rapid movement of air molecules, by virtue of heat disturbance, will also disturb electrical equilibrium.

It is not enough, then, to maintain a condition in which the *average* absolute humidity of the air within a room is sufficiently high to make such mixture fairly conductive; it is essential that adequate conductivity in the localities where excessive disturbance exists be assured. This means that if the molecules of water vapor in space must be depended upon as a means of discharging generated static with sufficient facility to prevent troublesome accumulations, their number must be in ratio to the task. A small pipe can carry away a small amount of water or steam, and a copper wire of small diameter can conduct a small quantity of electricity with ease. But neither can accomplish the desired end and if the task imposed is beyond its ultimate capacity, and neither can be expected to serve its purpose, even if its capacity were ample, unless its position is such as to make it constantly available as a conveyor. This means real air conditioning, and the term as here employed contemplates not the control of temperature *or* humidity *or* air motion, but the actual control of all three.

Steam Trap Records Pave Way to Savings

By T. H. Rea

A FACT is a fact and is always the same. An opinion may vary with what you had for breakfast," according to C. F. Kettering of the General Motors and Delco Light Corporations. In building a power-dam, the engineer does not attempt to guess the flow of water in the river, the seasonal variation in the flow, or the depth and quality of the bedrock. He simply cannot afford to guess—he must get the facts. After the necessary surveys have been completed and all the required data are at hand, it is a relatively simple matter to draw up the plans and estimate the cost of the project.

The engineer, master mechanic, boss pipe-fitter, superintendent or whoever may be in charge of steam distribution is frequently called on for recommendations concerning the selection of additional equipment. Unless records have ben kept showing the performance of the equipment in question, the recommendation is based upon opinion rather than fact and opinions are not a safe guide, especially when facts are so easy to obtain.

Record System Applicable to Other Equipment

While the following remarks are confined to the subject of steam trap performance records and costs, similar methods can be used to obtain figures on the service given by other types of equipment such as reducing valves, pressure and temperature regulators, valves, pumps, in fact on all items used in the plant. The system described in the following paragraphs is similar to that followed in a number of the leading industrial plants and although no two are exactly alike, the basic principle is the same.

In order to obtain complete information on steam trap maintenance costs, three things are necessary. First, a record card for each trap installed in the plant; second, a record card for each kind and size of repair part used or carried in stock; third, periodic inspection and a method for recording labor and repair parts costs to the individual trap record cards.

The Trap Card

The trap card, such as shown in Fig. 1, should have spaces for all the information indicated and such additional data as may be necessary for an individual plant. Record-keeping will be greatly simplified by assigning a plant serial number to each trap as it is installed. This plant serial number on work orders and repair parts requisitions will insure charges being made to the proper trap. All trap cards should be kept in one file and a single individual should be responsible for making all the charges against the traps. As a matter of fact these trap record cards, together with the cards for all other items of equipment, are nothing more or less than a detailed equipment ledger. However, so far as getting trap costs is concerned, it is immaterial whether or not this detailed equipment ledger is tied in with the general accounting system. Such a tie-up can be made easily and is advisable unless it involves considerable bother and expense.

The size of the trap card depends on the user's requirements but in no case should a card smaller than 5 x 7 be used. On smaller cards it is impossible to make enough entries to carry the record over a number of years.

The repair parts card can well be the same size as the trap or equipment card and can be kept in a separate file as are the trap cards. This card should contain enough information to identify completely the repair part in question. If a perpetual supply stores inventory is maintained showing the number and kind of repair parts and material on hand at all times, as well as the cost, it is unnecessary to set up a duplicate set of records covering trap repair parts.

All repair parts purchased should be entered on these cards indicating the date purchased, number of parts, purchase order number, and cost laid down at the plant.

MAKE A LOCATION Bldg 2 PLANT SERIAL NO. 491

SIZE OF TRAP 4 CONNECTIONS 1" MFG. SERIAL NO. 11998

MAXIMUM PRESSURE 150

1923 7/29	Cost	25	80				
1926 9/17	Parts Req 17624	1	53				
-	Labor		75				

FIG. 1

NAME OF PART *Valve Orifice*
FOR *Trap A* SIZE *4* CONN *1"* PRESSURE *150*
MAX *6* MIN *3*

Date	Ref	Amt	Date	Ref	Amt	Balance on Hand
1926 9/14	Order 24762 6 pcs	9 18	1926 9/17	Req 17624 Trap 491	1 53	5

When a part is taken out of stock for use in a trap, a corresponding credit should be made.

Use of Records

The question will probably be asked "Why go to the trouble of keeping these repair parts cards?"

Aside from their value as a perpetual inventory record they indicate approximately how many of each repair part should be carried in stock. Thus they not only insure an adequate stock of repair parts on hand at all times but also, and what is equally important, prevent building up excess stocks of these parts. For instance if a card shows that three of a certain size and make of bucket have been used in the space of four years, it is obviously unnecessary to carry twelve of these parts on hand. Likewise if twenty-five of a certain part are used every year, a stock of two of these parts is by no means adequate.

Using similar records one company reduced its repair parts inventory from nearly $100,000.00 to less than $30,000.00 and during the same time its general business doubled. Under the old system of hit-or-miss repair part purchases, it probably would have had anywhere from $150,000.00 to $200,000.00 tied up in parts. Hence the perpetual inventory system saved the interest on well over $100,000.00—more than enough to pay the expense of the repair card system without considering the other benefits derived.

Inspection and Repairs

A steam trap, like any other piece of equipment, is entitled to periodic inspection and repair. In addition to this regular check on the condition of the trap mechanism, a daily test of each trap is desirable to make sure that it is operating as it should. A trap body may become filled with dirt or sludge, putting it out of commission and making it worse than if no trap at all were installed on the job. Or perhaps a trap will stick open with a resulting steam loss. Assuming a steam cost of 50 cents per thousand pounds, a trap having a 3/8-inch discharge orifice at 100 pounds steam pressure can waste $7.25 worth of steam per day, which is more than enough to pay the cost of inspecting several hundred traps. Nor is the steam loss from the trap the only factor to be considered. Steam blowing through a trap will, in a short time, score the orifice and damage the operating mechanism to such an extent that a complete new mechanism is necessary instead of a slight lapping in or a mere removal of the scale or dirt interfering with the trap operation, as would be the case with daily inspection in force.

FIG. 2

In order to make a daily inspection practical, the trap must be so installed that the discharge can be observed easily. A three-way valve that automatically shuts the return line before the trap can discharge to the atmosphere makes a very simple installation. Otherwise two valves should be used as shown in Fig. 3, valve *A* being closed before *B* is opened so that back pressure in the return line will not be confused for steam blowing through the trap.

The adoption of standard trap connections either with or without a by-pass not only facilitates trap inspection but makes it possible to put a replacement trap on the line in just a few moments so that the defective trap can be taken to the machine shop for repair or reconditioning. Standard trap connections are just as easy to make as the ordinary "cut and fit" variety. All that is necessary is to have the inlet and outlet nipple identical in length and shape for all traps of a given make and size. Then to replace a trap it is only necessary to break two unions (or two flanges), remove the trap, and then tighten up the unions for the replacement trap. (See Fig. 4.)

The individual making the daily trap inspection should plan to take the shortest possible route through the plant. An experienced man can tell quickly, by observing the discharge, whether or not the trap is operating as it should. If the trap is blowing continuously, it probably indicates a piece of scale in the valve orifice or else the trap has lost its prime. Closing the inlet valve for a few minutes to allow condensate to accumulate and then opening the valve again is frequently sufficient to correct this difficulty. If not, or if the trap is cold and does not discharge any condensate at all, the interior mechanism should be examined. Perhaps all the trap needs is a cleaning. However, if the inspector finds that considerable work is required, a work order, bearing the trap number, should be made out and the trap put in first class condition by a competent mechanic. The mechanic's time as well as the parts used should be charged on the trap card and, of course, proper credit made on the repair parts cards.

Charges to Each Trap and Prorating Inspection Time

At the end of the year, the total labor and parts charges to each trap should be found. Whether or not the inspector's time should be prorated over the traps is a matter of policy. In any event, it is well to keep this item separate from the charges for parts and repair labor. The total labor and repair parts cost for each make of trap should be divided by the total number of that particular make to get the average cost per trap per year. This figure, assuming that there are enough traps in service to make a comparison worth while, is the one that is used to determine what make of trap should be

used in that plant or for a particular department in the plant. In making a recommendation based on these figures, the superintendent or engineer is not venturing an opinion but simply stating facts.

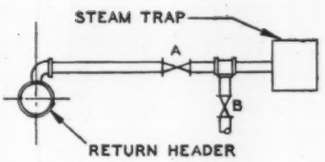


FIG. 3—TEST VALVE HOOK-UP

The cost of keeping traps repaired and in first class operating condition is not the only factor to be considered. Reliability is even more important than costs and the records can be so kept that whenever a trap requires attention, the fact is noted on the trap card. Usually the low repair cost trap is the more reliable but this is not necessarily the case. When the cards show that the most reliable trap is not the low cost trap, it is good judgment to recommend the more reliable trap for draining separators and process equipment where a spoiled batch would cost far more than several traps.

The fact-finding system need not be complicated and is essentially a daily or other periodic inspection, a card for each trap to which all charges for material and labor can be made, and a card for each repair part to serve as an inventory record and a guide for future purchases.

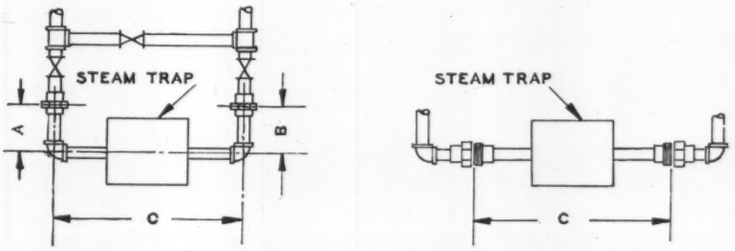


FIG. 4—STANDARD TRAP CONNECTIONS. DISTANCES *A*, *B* AND *C* SHOULD BE THE SAME FOR ALL TRAPS OF THE SAME SIZE AND MAKE

Traps have been mentioned in this article merely as a matter of convenience—it is equally applicable to pumps and reducing valves or any other item of power plant and steam distribution equipment. Any engineer working with the accounting department can work out a similar system exactly suited to the needs of the plant.

One instance is cited to show the advantage of facts over opinions. Records in one plant indicated that valve *A* was better than competing makes. In order to get a comparative test under identical operating conditions, six different valves were installed on six kettles of a size in one department. Valve *A* was one of the six valves and when the engineer in charge asked the operator how he liked valve *A*, the engineer was surprised to hear the operator say the valve was "no good." Was this a case where the records did not agree with practice? Hardly, for the operator's objection, on further questioning, was that there were no knobs on the valve handle with which he could gauge the position of the valve. The handle was changed, and a few days later the same operator reported that valve *A* was by far the best valve he had ever used. All of which goes to prove that "facts are facts but opinions may vary with the kind of handle or color of paint, or what you had for breakfast." And it is facts we want.

Cell Concrete for Insulating Steam Lines

AN interesting application of cell concrete to underground pipe mains in Copenhagen was recently observed by the writer. The city desired to heat a hospital from one of the older electric stations one and a half miles away. Trenches were dug and a concrete base slab was poured, after which the steam and return pipes were laid. These were tested for tightness and then wrapped with heavy oiled paper which provided the necessary clearance for the pipe to slide through the cell concrete later when expanding or contracting. Forms were then placed around the covered pipe and cell concrete was poured around the complete nest of pipes in the trench. When this had set, the forms were moved out and the insulating cell concrete was covered with an arched layer of reinforced concrete to carry the earth load and the weight due to traffic on the street above.

Another use for this material was discovered at the Municipal Electrical Central Station of Copenhagen, where it is used for covering the breechings behind the boilers. The cell concrete had been poured into sheet steel trays about 1 in. deep and was allowed to set. Then these trays were welded to holding strips on the outside of the breeching. This material served as an effective insulation, for the surface was only warm while the flue gas temperature in the breeching was about 600 F. This method of covering was said to be inexpensive.

These applications of cell concrete caused the writer to investigate it further, and to visit a plant where it was being made.

Cell concrete is a patented process of Christiani and Nielsen, Copenhagen. It is made in the following manner:

Portland cement, sand and water are added in the desired proportions to a standard concrete mixer which is run until the constituents have formed a mortar. A rotary machine is placed at the side of the mixer into which certain oils, similar to those used in flotation processes for the recovery of minerals, are added and churned to a thick creamy foam consisting of millions of fine air bubbles.

The proper amount of this foam to give the desired final density of the cell concrete is scooped into the cement mixer. The mixer is run at high speed for about two minutes to thoroughly mix the foam into the mortar, the bubbles breaking up into very small spheres. It is then poured as a soupy mixture into forms. Quick setting cements are used so that the first set takes place long before the bubbles collapse. The resultant concrete consists of an open porous mass with millions of small cells.

The weight of cell concrete depends upon the amount of foam added to the mixer. It may be as low as 20 lb. per cu. ft.

Cell concrete is used quite extensively in building construction, being cast into blocks. These blocks are readily sawed into any desired shapes after the first set and are then cured for use.—*A. G. Christie.*

Air Filtering for Pneumatic Coal Cleaning Plants

By Charles H. J. Patterson

Until recent years, coal preparation was one of the few major industries practically free from air conditioning problems, but with the introduction of the pneumatic separator for coal preparation, the situation was altered considerably. Several plants now use air volumes of 200,000 c.f.m. and others are being designed of ten times that capacity, all of which call for the same general corrective treatment.

AT certain stages in almost every modern process of production, fabrication or refinement, some obnoxious fumes or some forms of dust are produced or liberated. These, if released to the atmosphere, may constitute a grave nuisance, if not an actual menace, and present day health regulations do not countenance such atmospheric contamination. As a result, most important industries today employ some form of air conditioning equipment. The plants requiring such systems may be roughly divided into three general classes:

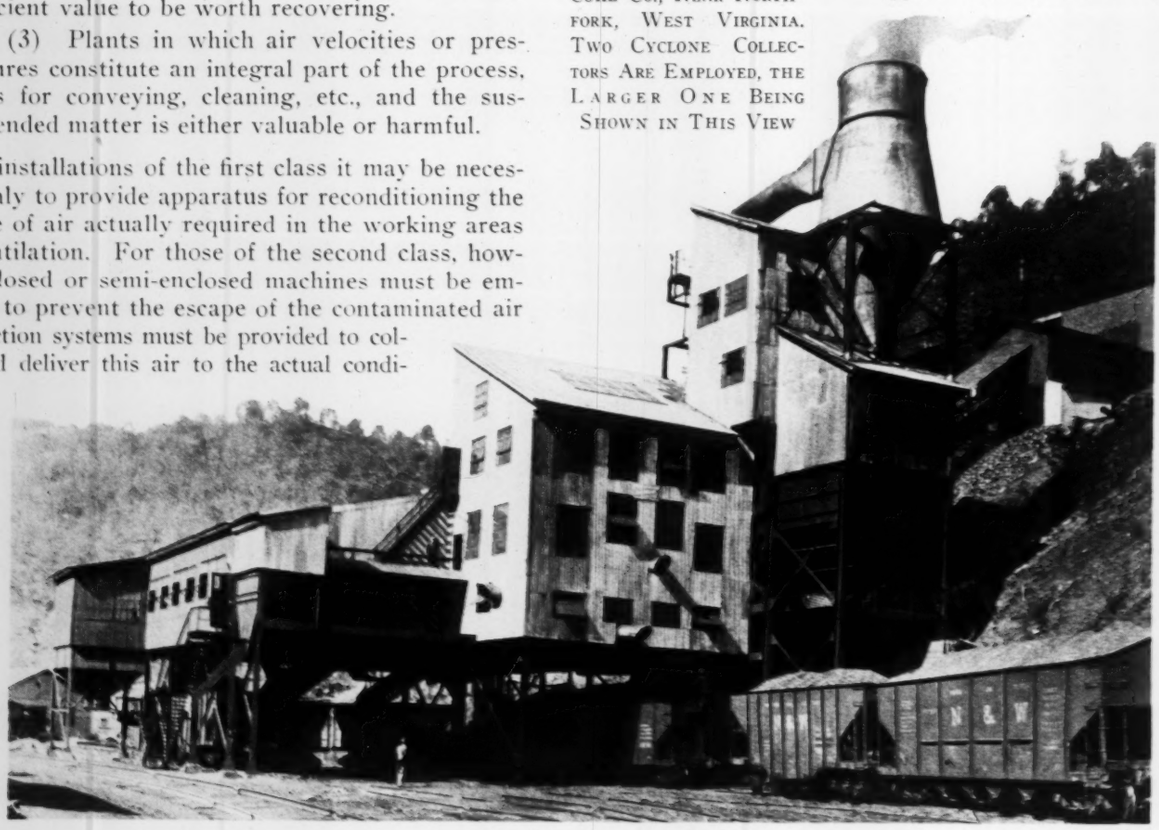
(1) Plants in which the air is not so polluted as to be unfit for respiration but might result in a public nuisance if allowed beyond the confines of the plant.

(2) Plants in which the volatile or suspensible by-products are truly obnoxious and cannot be released even inside the plant, or are of sufficient value to be worth recovering.

(3) Plants in which air velocities or pressures constitute an integral part of the process, as for conveying, cleaning, etc., and the suspended matter is either valuable or harmful.

For installations of the first class it may be necessary only to provide apparatus for reconditioning the volume of air actually required in the working areas for ventilation. For those of the second class, however, closed or semi-enclosed machines must be employed to prevent the escape of the contaminated air and suction systems must be provided to collect and deliver this air to the actual conditioning units. These latter must ordinarily be larger or more numerous because of the increased volumes handled and the necessity for complete removal of the suspended matter. The third class of plant presents much the same problem as the second except that the volumes are further increased and larger equipment is necessitated throughout.

Two general types of systems are used for plants of the third class. The air used in the process can be collected and conditioned and then released to the atmosphere, fresh air being taken in to maintain the operation of the process, or the same air may be used repeatedly in the so-called "closed-circuit" systems. These are continuous, sealed systems in which the process air is recirculated through the machines with only partial conditioning, or none at all. This might appear to obviate the



COAL CLEANING PLANT OF THE GILLIAM COAL & COKE CO., NEAR NORTHFORK, WEST VIRGINIA. TWO CYCLONE COLLECTORS ARE EMPLOYED, THE LARGER ONE BEING SHOWN IN THIS VIEW

necessity for conditioning equipment, but in reality it does not do so. The air circuit of any such system must be interrupted at certain points, if only for the introduction of raw materials and recovery of finished products. It is entirely possible to do this without permitting the escape of contaminated air but it is not practical to do so without admitting at least a small amount of air into the circuit from the outside. This action is continuous and accumulative and soon results in an excessive volume of air in the circuit. The velocity is correspondingly increased and a serious waste of power effected, even if the operation of the process is not unbalanced. Means must be provided, therefore, for the emission of this extraneous air, which must also be subjected to some conditioning treatment if the protection is to be complete.

In view of these facts and of the varying means and difficulties of separating different substances from air, it is readily understandable that many and divers forms of equipment have been developed for this service in the various industries. To discuss them all even briefly would require a monumental volume, so the present article is restricted to such as are employed in connection with coal preparation plants.

The Pneumatic Separator

Until recent years, coal preparation was one of the few major industries practically free from air conditioning problems. Such dust as might be liberated in dumping, crushing, screening and conveying ordinarily settled within the limits of the plant and if interior conditions became objectionable, sprinkling afforded a simple and economical remedy. Coal cleaning, i. e., the removal of impurities, was formerly attempted only by wet washery methods and there was no opportunity for dust discharge. With the introduction of the pneumatic separator for coal preparation, the situation was radically altered. These machines consist of reciprocating, pervious decks, mounted over confined air chests which are connected with blower fans. The raw coal is deposited upon these decks and the jets of air, escaping upward from the air chests through the interstices of the deck covering, agitate the mass and keep it in partial suspension. The heavier particles, including most of the high-ash impurities, naturally sink to the bottom and are diverted by a series of vanes or riffles to one edge of the deck. The lighter, clean fuel flows over the tops of the riffles to discharge into conveyors or other receptacles. It is virtually a flotation process, air under pressure being substituted for water or other liquid as the flotation medium.

Volume of Air Used

The volume, pressure and velocity of air used vary with operating requirements, but in all cases the air after passing through the deck and the bed of coal retains some residual velocity which naturally takes up and holds in suspension a large percentage of the fine dust present in the conglomerate mass of the coal. The larger and heavier particles soon precipitate as the air loses its velocity but a large proportion, especially of the extremely fine so-called "air-float" dust, remains almost indefinitely in suspension and would obviously create an intolerable situation if not immediately remedied.

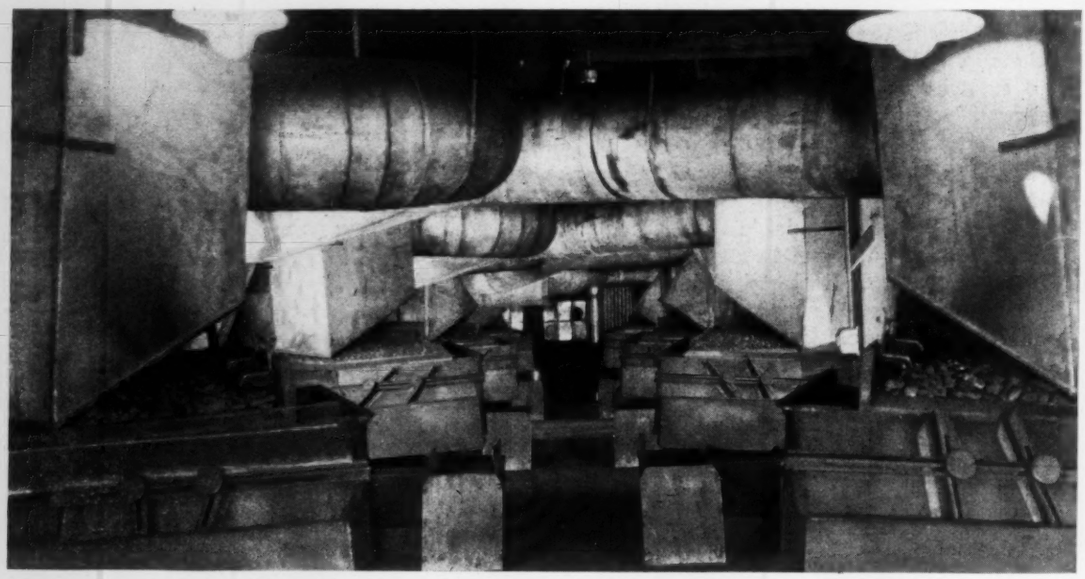
Interior of the Tube Compartment in an English Plant. The Bottom of the Expansion Chamber Is Visible Over the Tubes, and the Tops of the Dust Hoppers Extend Above the Floor. Louvred Walls Permit the Escape of Filtered Air

Individual units require from 3,000 to 30,000 cubic feet of air per minute, depending upon the sizes, type and tonnage of coal treated, and as many as fifteen or twenty units are employed in some of the larger plants. Several plants now in operation have total air volumes in excess of 200,000 c.f.m. and an exceptionally large plant now being designed is reputed to provide for ten times that volume. These quantities are enormous as compared with plants of corresponding size and capacity in other industries; although these plants come within the limits of the third class listed above and call for the same general corrective treatment, the greater magnitude of the system places them practically in a class by themselves.

The earlier plants treated only the larger sizes of coal, all material finer than one-eighth inch being screened out before feeding onto the decks. Only such dust as adhered to the larger particles of coal entered the process at all and so the unit dust burden of the exhaust air was extremely low. Moreover, they were mostly small plants and the total air volumes correspondingly low, all of which simplified the air conditioning problem. The systems used were really elementary, dust hoods being provided over the decks and connected by systems of ducts to exhaust fans, which in turn delivered into centrifugal

collectors or "cyclones." The design of the hoods permitted considerable air to escape into the plant but its dust burden was so low as not to be seriously objectionable. Similarly, much of the air-float dust was discharged by the collectors into the atmosphere but was insufficient in amount or intensity to constitute any grave nuisance. The most notable difference from dust recovery systems of other industries lay in the comparatively large ducts, fans and collectors required.

quired for even an average-sized coal preparation plant. This multiplicity of units not only made the cost prohibitive but also tended to increase the complexity of plants already none too simple in design. The situation was further aggravated by the class of material to be handled. Fine coal dust is frequently very moist and occasionally extremely wet. Furthermore, it consists not only of coal but also of some of the impurities in the coal, usually hard and very abrasive. These factors minimize the useful life of



The Air Piping in Connection with the Dry Cleaning Tables at the Plant of the American Coal Co. at McComas, West Virginia

New Type of Deck for Fine Coal

Around 1923 a new type of deck was developed with a capacity just about twice that of the earlier models, without a corresponding increase in air requirement. This type was found to be admirably adapted to the treatment of fine coal and greatly widened the scope of the process but also intensified the dust recovery problem. The large amount of extremely fine dust present in the slack coal, coupled with the smaller air volumes required for its treatment by the new machine, increased enormously the relative dust burden of the exhaust air. Even a small amount of this heavily-laden air escaping inside the plant would seriously hamper operation and the escape of the air-float fines from the collectors made the adjacent neighborhood quite unfit for habitation. Cyclone collectors were palpably inadequate for this service and other types of reclaiming apparatus were investigated.

Action of Coal on Filters

Many varieties of air filters, employing tubes or sheets of fabric through which the air was filtered or screened, had long been in use in cement and grain mills and similar plants in other industries. All such filters then available, however, were designed on the basis of the relatively small air volumes of these industries and their standard units were of such low capacity that great numbers of them would be required for any known filter fabric unless very low velocities are used, which in turn demands a larger area of filtering surface and therefore more or larger units. Hence an even larger number of units would be required than for the same air volumes in other industries.

Considerable experiment and research were conducted along different lines, both here and in Great Britain, in the hope of finding an adequate and economical means of conditioning this air. The experiments in this country chiefly concerned water sprays and jets which might be used to supplement the centrifugal collectors, recovering the extremely fine material from the collector exhaust. None of these was entirely successful, due in a large measure to the difficulty of producing water globules small enough to entrap the very minute dust particles which constitute the prime difficulty of the whole problem. Live steam could undoubtedly have been more successful in this respect but in either case the process is incomplete. A mass of sludge, or at best a wet dust cake, is produced which must be disposed of separately in some other manner.

The stringent regulations governing industrial discharges in England made complete recovery a primary requisite there and filtering was early accepted as the logical method of recovering the extreme fines. Investigations were directed toward the elimination of filtering for the larger and more abrasive particles, and after extensive research the investigators

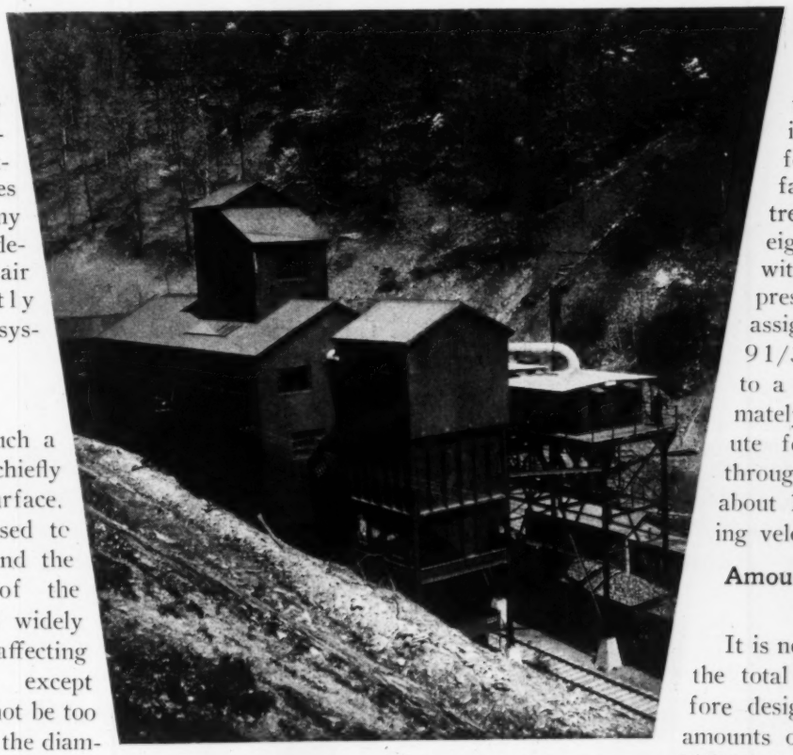
eventually returned to the simplest of all recovery principles, precipitation. The system finally evolved is a simple and effective combination of the two principles.

Equipment Used

The equipment employed is almost identical in form with the very simplest tube type filter used many years before the introduction of rapping and knocking devices and air reversing apparatus. In its principle of operation, however, it is entirely different. Vertical cylindrical tubes of a carefully chosen filter fabric are surmounted by a voluminous expansion chamber, into which the impregnated air is first introduced. The total filtering surface is so adjusted for any given volume of air that the speed of the air leaving the filter is not more than 1/750 of the entering velocity and ordinarily less. All but the finest particles of dust are precipated in the expansion chamber and as the velocity dissipates, drop vertically through the tubes to hoppers provided below. The extreme fines still in suspension are filtered or screened out as the air passes through the meshes of the filter fabric, the sole means of egress for the air. The entire unit is sealed and the valves or gates for drawing off the collected dust are so designed as to prevent the escape of air. Since the larger and more abrasive particles are not thrown directly against the fabric, higher air velocities are permissible than can safely be used with the direct-screening type of unit and this, of course, reduces the total fabric area required. In fact, the fabric serves chiefly as the supporting base for a thin film of extremely fine dust which, in operation, forms a protective lining inside the tube and seems really to constitute the actual filter. The thickness of this film is practically constant, the outermost particles falling off by gravity when a certain thickness is exceeded. This obviates the necessity for any knocking or rapping devices or reversal of air current and greatly simplifies the entire system.

Capacity

The capacity of such a unit is determined chiefly by the total filter surface, or fabric area, exposed to the filtering action and the actual proportions of the tubes may be varied widely without noticeably affecting operating efficiency, except that the length must not be too great in proportion to the diameter. The writer has suggested the rule, entirely arbitrary, that *the length in feet must never exceed the circumference in inches.* For convenience of design and economy of manufacture, a tube seven inches in diameter by nineteen feet six inches long has been arbitrarily chosen as standard in the United States and is used in all plants now in operation or under construction which incorporate this type of recovery equipment. These tubes are affixed at top and bottom by means of straps to standard cast iron "spigots." Several inches of coarse fabric are provided at each end of the tube for strapping and to make the entire standard length effective for filtration. In the latter plants, slightly conical "thimbles" of light gauge metal are inserted loosely in the upper spigots, extending about fifteen inches downward into the tubes. This directs the falling particles toward the centers of the tubes and avoids abrasion of the dust film.



A Coal Cleaning Plant in Virginia, Showing the Dust Arresters

Number of Tubes Required

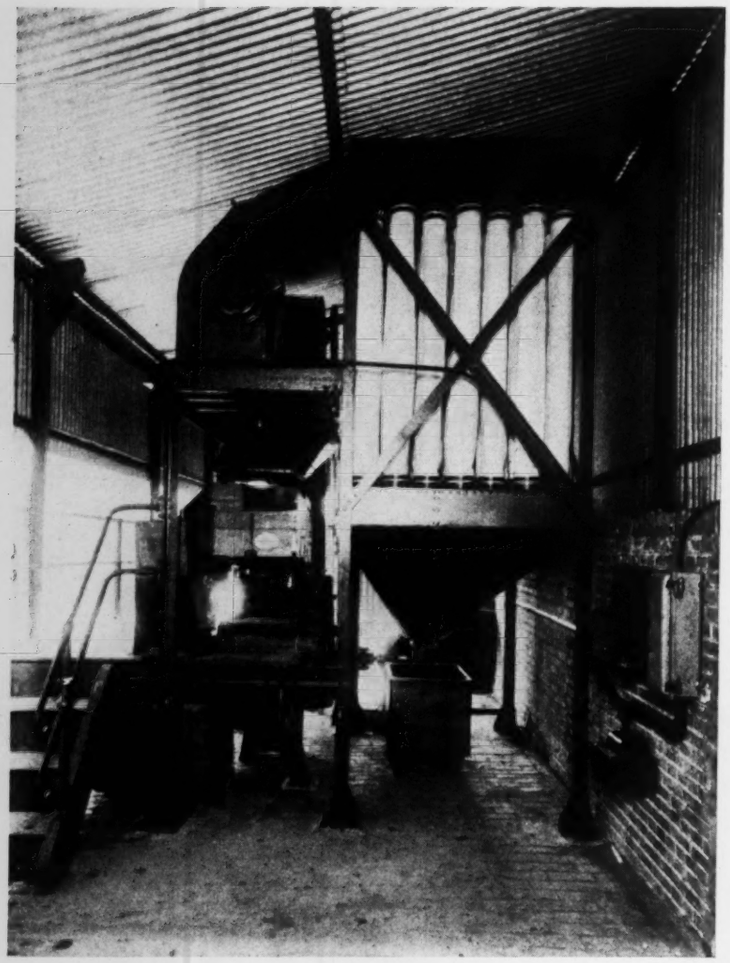
The arrangement of the tubes in plan may be such as will most conveniently fit into the space available, but the number of tubes required depends primarily upon the total volume of air and in a less degree upon the unit dust burden. This latter cannot be conveniently determined directly, but is known to vary with operating conditions, and is so introduced into the following formula, which is largely empirical:

$$\text{The number of standard tubes required is } N = \frac{V \times F}{1000},$$

where V is the total volume of air and F is a variable factor. For ideal conditions, treating the larger sizes of coal only, F may be taken as 7. For average plants, treating large and small sizes, use 8. When only the smaller sizes are treated, F should be increased to 9 and for extremely unfavorable conditions, treating coal under one-eighth inch only, or with unusual moisture present, F is usually assigned a value of about 9 1/3, which corresponds to a velocity of approximately three feet per minute for the air escaping through the fabric, or about 1/1000 of the entering velocity.

Amount of Surplus Air Necessary

It is necessary to determine the total volume of air before designing a filter. The amounts of air furnished the individual separators for different conditions of operation



A Special Half-Size Separator for Fuel Research Installed at Birmingham University, England. Individual Tube Type Dust Recovery Is Used

are on file with the manufacturers of each type. In addition to the air actually used by the separator, a certain amount of "surplus air" must be taken in around the edges of the hood or through the discharge ports and inspection openings of enclosed machines, so that a positive inward current may be insured at these points. This prevents any possibility of dust-laden air escaping into the plant. There is no known means for accurately determining the proper volume of air for this purpose, but for convenience it is usually expressed in percentages of the total volume furnished to the separator. The following percentages have been arbitrarily chosen but are largely in use by designers of such plants:

For separators treating coal larger than one inch	5 per cent
For coal between one inch and one-eighth inch	10 per cent
For coal smaller than one-eighth inch	20 per cent

For totally enclosed machines, as used in Europe, with openings only for the discharge of materials and for inspection, these percentages may safely be cut in half. Any additional air volume used to collect dust from screens, crushers, conveyors, and other auxiliary equipment are computed in the usual manner, but must be provided for in the design of the recovery unit.

Size and Speed of Exhauster

To determine the size and operating speed of the exhauster, it is, of course, necessary to know the resistance or back pressure of the conditioning unit and for the equipment described above the following formula is sufficiently accurate:

Collector resistance, in ounces per square inch, is given by $R_c = \frac{16}{3F}$, where F is the same factor used in determining the number of tubes required.* Actual readings in operating plants record resistances considerably lower than those indicated by the above formula, but such low figures are not recommended as entirely safe for general design.

The resistances of the piping circuits are of course computed in the same manner as for similar installations in other industries and space is not now available for recording all the pertinent specifications and engineering data. It might be well to point out, however, that the total resistance is taken as the sum of the resistances of the ducts and the collector, the usual "hood suction loss" being neglected entirely. This practice is based on the assumption that the residual velocity of the air after having passed through the deck and the coal bed is at least sufficient to neutralize the losses occasioned by the suction resistance of the small percentage of surplus air taken in from the outside. This seems to prove out in actual operation.

Standard Units Available

In closing, it should be remarked that, following the broader developments of the pneumatic process, some of the older filter manufacturers have introduced standard units of larger proportion and capacity, making them more adaptable to this class of service. Mechanical rapping or shaking devices are still necessary and the back pressures seem to be somewhat higher than for the units described above, but they are in satisfactory operation in several recent plants, including plants of the Humphreys Coal & Coke Company, Greensburg, Pa.; Hillman Coal & Coke Company, Jerome, Pa.; and Berwind-White Coal Company, Windber, Pa.

Capacities, resistances and other engineering data pertaining to these filters can no doubt be obtained from the manufacturers. The type of equipment dealt with in this article is used exclusively in European plants treating small coal, as well as in Australia, and in many modern American plants. Centrifugal collectors are still employed in many plants.

* This resistance can be expressed in inches of water as $Rc = \frac{9.2}{F}$.

Stopping a Fan Noise

By Louis L. Narowetz, Jr.

CONSULTING engineers and contractors frequently encounter problems that are most baffling in the elimination of noise from heating and ventilating equipment. Sometimes the fan is blamed for the disturbance when the noise comes from some other piece of machinery or from some remote or little suspected source.

The writer recalls such an instance in an office building when the fan was blamed for a thumping noise that occurred at regular intervals. It was thought at first that the trouble was with the fan bearings. Then it was believed that the wheel was out of alignment. But all efforts to find the cause of the noise in the fan were of no avail. The source was discovered eventually, however, and this instance serves to show how unusual are some of the problems that occur in noise elimination.

Noise Transmitted by Conduit

It was found that the electrical conduit to the fan ran to it from a panel board in a manufacturing plant in a separate building. In the plant, a large press was connected by a conduit to the same panel board. The thumping of the press was transmitted to the panel board and through the electrical conduit to the fan motor. When the wiring connection was changed and taken from another board, the noise was eliminated.

Another unusual problem in eliminating noise in which the fan was indirectly responsible was more difficult of solution. Various tests were conducted in the search for the trouble. The complaint was with reference to a whistling noise in a recent supply fan installation in a large gymnasium and its locker rooms.

This system was designed to handle 27,500 c.f.m. It had the regulation air intake screen, copper louvres, air control shut-off dampers and air intake duct large enough so that the velocity was less than 1,000 f.p.m. There was one disadvantage; it was necessary to use a 90-degree elbow to bring the center line of the apparatus at right angles to the original air intake opening. This elbow increased in section at the intake end from 29 sq. ft. to 54 sq. ft. at the connection to heater tempering coils. The air then passed through an air washer, through the reheater coils and then to the fan inlet.

The heater coils, air washer and fan were arranged so that one center line was common to all of them. The fan was set on a concrete slab 12 in. high with cork insulation 4 in. thick under its entire base. The fan was driven by an alternating current motor (belt-connected), and the foundation for the motor was integral with the fan base. Canvas connections were provided at both inlet and outlet of the fan.

After the system was installed, anemometer readings were taken at all supply outlets and adjustments were made, with final results showing about 10 per cent more air being delivered at the specified r.p.m. than was called for. Since the motor was equipped with a speed reduction device, it was a simple matter to change the fan speed so that the required amount of air was delivered.

It Whistled

With the plant operating at the speed necessary to deliver the required volume, namely 27,500 c.f.m., there was a pronounced whistle at all openings. This whistle increased in volume at openings nearest the fan discharge.

The usual investigation of air splits, joints, loose deflectors, etc., was made without locating the source of trouble. After this investigation, the fan was considered as being the source of trouble. It was thought that the cause was at the cut-off, and its edge was lined with felt without any improvement. During this operation, a man stood inside of the large fan discharge duct facing the discharge looking into the wheel, and he reported that the noise was in the center of the wheel and it was believed that the cause was improper balance.

At this time the fan manufacturers were called in to make a test of their equipment. During their investigation an access door was opened (*A*, Fig. 1) and the whistling noise disappeared.

Result of Test of Fan Manufacturers

The following is the report given by the fan manufacturers:

"The test on the fan used for supplying air for gymnasium shows the following performance:

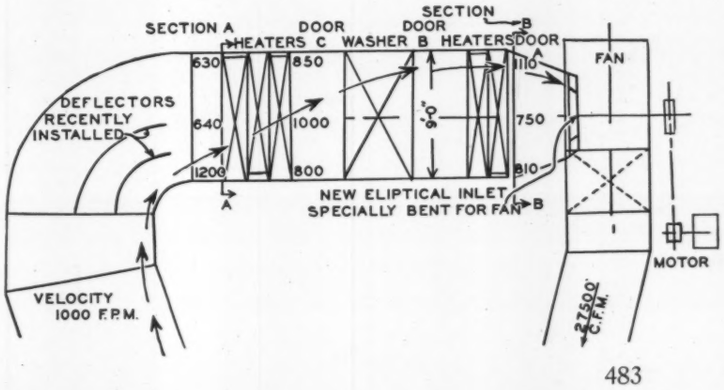


FIG. 1—A PLAN OF THE INSTALLATION. THE VELOCITIES SHOWN NEAR DOOR *C* WERE READ ACROSS THE CENTER OF THE DUCT; VELOCITIES AT THE TOP AND BOTTOM WERE MUCH LOWER

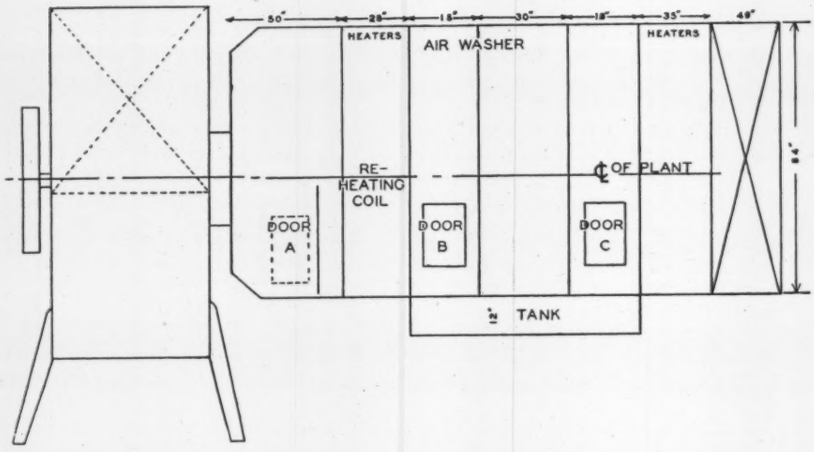


FIG. 2—AN ELEVATION SHOWING ARRANGEMENT OF THE EQUIPMENT. WITH DOORS *A*, *B* AND *C* CLOSED, AND THE FAN RUNNING AT NORMAL SPEED, THE WHISTLE WAS AUDIBLE ALL OVER THE BUILDING

Fan Test No. 1: Static pressure, 1.23 in.; r.p.m., 229; c.f.m., 28,800.

With the fan running at this speed, a sharp whistle is audible all over the building; not successful in locating this noise except that it was not audible on the intake side of the fan. The face area of the air washer used in conjunction with this fan is 57 sq. ft., which gives a velocity of 505 ft. per minute. Decreasing the speed of the fan until the whistle stopped the following results were obtained.

Fan Test No. 2: Static pressure, 0.695 in.; r.p.m., 160, c.f.m., 17,600.

The whistle is heard at all speeds above 160 r.p.m., increasing in magnitude with the speed. The specifications call for a fan for the following duty: Static pressure, 1.25 in.; r.p.m., 230; c.f.m., 27,500.

The fan tested is fulfilling the duty for which it was selected, except for the whistle above 160 r.p.m."

Another test showed the following: The duct measured 49 in. x 84 in. at point where readings were taken: Static pressure, 1.32 in.; velocity pressure, 0.114 in.; r.p.m., 228; c.f.m., 31,200.

Peculiar Noise Phenomena

1. With doors *A* and *B* closed and *C* open, the noise was still heard.
2. With doors *A* closed and *B* and *C* open it was still as noisy.
3. With *A* closed, *B* open and *C* closed, it was noisy.
4. With doors, *A*, *B* and *C* open the system was quiet all over the building.
5. With *A* and *B* open and *C* closed the system was quiet.
6. With *A* open, *B* closed and *C* open the system was quiet.
7. With *A* open and *B* and *C* closed the system was quiet.

By this test it is shown that whenever the door *A* was left closed, the system whistled but when door *A* was opened the system became quiet. From this it seemed quite plausible that the whistle occurred between the inlet of the fan and the reheating coil.

The velocity pressures obtained were very irregular, so the velocity pressure used in the average of ten readings (taken on a horizontal and vertical traverse of the duct which measured 49 in. by 84 in.) were taken at the only available point. This point was immediately in front of a compound bend, so they were not dependable, but were the best that could be obtained with the short pitot tube.

It was suggested that the noise was caused by uneven velocity of air passing through the conditioning apparatus, and a consequent check up was made with the following report and sketch with data submitted:

"Velocity readings, see Fig. 3, were made at the locations shown with an anemometer, the fan running at 230 r.p.m. Readings were taken at the centers of six equal areas. The velocities shown are maximums, the higher velocity for the upper or lower

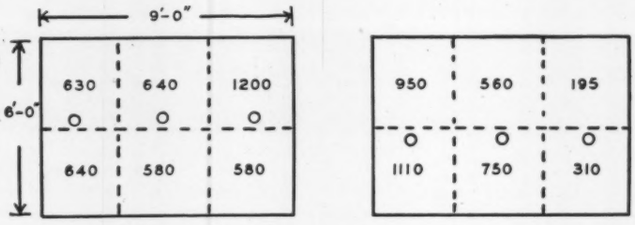


FIG. 3—VELOCITY READINGS OBTAINED IN ONE TEST, FACING TOWARD FAN IN DIRECTION OF AIR FLOW

traverse being used in each case. The arrows in Fig. 1 indicate the path of the main air stream.

The velocities varied so greatly at the various points that this air stream could be checked by actual observations inside the duct. (See Fig. 1.) Fig. 3 shows air velocities in feet per minute over the face areas at the two sections. Section *A-A* is the entering side of the tempering coils, and section *B-B* the leaving side of the heating coils.

Previous readings at a lower fan speed showed a fairly constant velocity for the air entering the washer, although there was a maximum through the center section.

The fresh air intake is approximately three feet higher than the duct, consequently there is a tendency for the air to follow the top of the duct, as well as the inside wall of the elbow. It may be necessary to place a deflector at a point in the duct ahead of the door to direct the air downward.

The two curved deflectors now in position lie in the natural path of the air, and have no appreciable effect on the air."

The curved deflectors shown in the large transition elbow were installed after the first report of noise was made but they did not alter the path of air to any perceptible degree. It was further sug-

gested that a section of adjustable diffuser blades 3 ft. x 3 ft. be installed between air washer and reheater coils. This was done without any improvement in distribution or reduction of noise.

Noise Eliminated by Elliptical Inlet Ring

During all these experiments, the writer maintained that the noise was in the fan inlet, which belief was based on the fact that when a segment of a circle was cut from some wall board and held in the fan inlet ring at the side adjacent to door *A*, the noise was eliminated. After a final conference, it was decided to install a cast iron inlet ring, and this being done the noise was entirely eliminated. The fan could be run at any speed and the distribution was much more even throughout the heaters and the air washer.

Although this trouble job appeared very simple, as the investigation developed, it was very puzzling at one time. Although the noise was eliminated, the real cause of the whistle and the various other phenomena encountered on this job are still a mystery to all concerned.

Investigation of Fan Performance First Step

The writer has used many fans of the same type as used on this job with success and he believes that unusual troubles may arise on any job where similar conditions are encountered. In endeavoring to discover the cause of noise in connection with ventilating equipment, the writer first makes an investigation of the performance of the fan.

Welded Pressure Vessels

A great many welded pressure vessels have been built under proper control methods during the past three years. These include high pressure storage tanks for gases and extremely volatile liquids, condensers, reaction tanks, columns, and a considerable variety of special types of pressure equipment.

One example is a complete creosoting unit, designed throughout for a fiber stress of 9,000 lb. per sq. in. This unit comprises the following equipment:

1. Rueping tank, 55 ft. long, 90 in. in diameter, with 11/16 in. shell. Working pressure, 125 lb. per sq. in.

2. Creosoting cylinders, each 90 ft. long, 90 in. in diameter, with shell 1-in. thick. Working pressure, 200 lb. per sq. in. These were the largest welded pressure vessels that had been constructed up to that time.

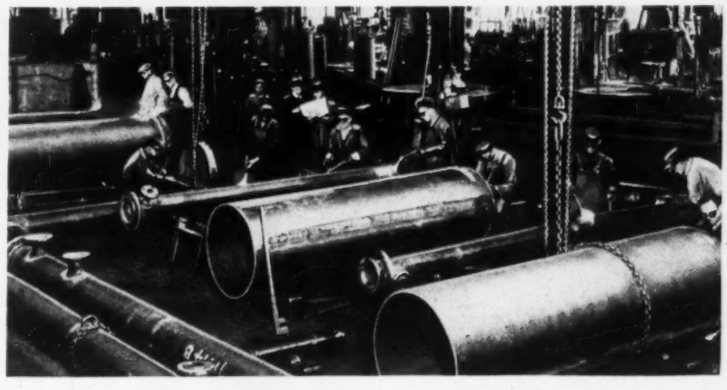
3. Pressure measuring tanks, 15 ft. 8 in. high, 90 in. in diameter, with shell 1 in. thick. Working pressure, 200 lb. per sq. in.

This unit has been in operation for some time with satisfactory results. There is complete freedom from leakage. The smooth inside of the welded cylinder also removes a source of annoyance that is present in some older types. Ties to be creosoted are placed in cars having steel bands or hoops to keep the ties in place. In order to obtain a maximum charge, the clearance is quite small, and occasionally a car would get caught on the seams of older type cylinders, thus interfering with the production schedule. This can not happen with the welded cylinder.

Building Up Welding Organizations

THE MAINTENANCE engineer in a plant where much welding of pressure vessels is required has a choice of two methods of building up an efficient welding personnel. He may train his own men for the work or he may obtain outside men selected on the basis of their ability to pass the qualification test.

For pressure vessel work, experience seems to indicate that, with a good nucleus as a starting point, the former method gives better results. It has been found that an inexperienced man of proper initiative and reliability can, after a relatively short period of training, produce more satisfactory results than a welder of many years' experience on miscellaneous applications.



Workmen Welding Pressure Vessels

In training an inexperienced man, the first step is usually to have him act as welder's helper. In this way he becomes familiar with methods used in handling the work, and in controlling alignment and seam contraction. At intervals, he is allowed to weld scrap material, first light, then heavier, under the direct supervision of the welding foreman. After some proficiency has been obtained, strips cut from his welds are broken through the weld in a vise and examined. Any defects such as insufficient penetration or poor fusion are pointed out and the manner of correcting them explained. Finally, when the welding foreman is satisfied with the progress, a qualification test specimen is made and sent to the laboratory, where it is submitted to the usual tests. After passing the test, the welder is first placed on work which can be readily observed, and where welding conditions are least difficult. As experience is acquired, he is permitted to do more exacting work.

Uni-Power Curves and Refrigeration Calculations

By W. R. Woolrich* and A. H. Cooper*

IN THE refrigeration process, the refrigerant merely acts as a heat carrier from one phase of the process to another. In the commercial compressor system, heat is added to the refrigerant (1) by the refrigerator and (2) by the compressor. Heat is taken from the refrigerant, usually, (1) by the compressor cooling water, (2) by line radiation and (3) by the condensing water.

As to the first step to determine how much theoretical work is being done per ton of refrigeration by the compressor, it is first desirable to determine how much refrigerant must be pumped per minute or how to produce refrigeration at the rate of one ton per 24 hours under the conditions of operation. When this value has been determined and the inlet and outlet temperatures and pressures have been measured, the theoretical heat added by the compressor per minute or hour to the required amount of refrigerant will give a measure of the horsepower being required per ton of refrigeration produced.

To explain clearly these computations, it will be advisable to define first some of the fundamental units used in the calculations involved. These definitions should include (a) ton of refrigeration, (b) refrigerating effect, (c) heat value of compression, (d) coefficient of performance, (e) adiabatic compression.

Ton of Refrigeration

The removal of 200 B.tu per minute for 24 hours is equal to one ton of refrigeration. This is based on the latent heat of fusion of ice taken as 144 B.tu per pound or 288,000 B.tu per ton. The removal of 288,000 B.tu in 24 hours is equal to the removal of 200 B.tu per minute.

Problem 1: A refrigerator requires the removal of 51,000 B.tu per hour to maintain it at 20 F. How much refrigeration is needed?

Computation:

$$51{,}000 \div 60 = 850 \text{ B.tu per minute}$$

Since 200 B.tu per minute equals one ton of refrigeration, the required tonnage is $850 \div 200 = 4.25$ tons.

Problem 2: Ten tons of apples require the extraction of 900,000 B.tu in 12 hours. How much theoretical refrigeration is required?

Computation:

$900{,}000 \div (12 \times 60) = 1{,}250$ B.tu to be removed per minute.

200 B.tu per minute equals one ton of refrigeration.

$1{,}250 \div 200 = 6.25$ tons of refrigeration required.

Refrigerating Effect

The heat content difference before entering and after leaving the evaporator or cooler, found by subtracting the heat content of one pound of refrigerant just before it passes through the expansion valve from the heat content just before it enters the compressor inlet valve, is known as the *refrigerating effect.*

All of the cooling ability of the refrigerating effect may not be utilized for effective refrigeration, since some of it is usually lost by radiation. Nevertheless, it is available if the necessary measures are taken to conserve it for the purpose produced.

Problem 1: The heat of the liquid of a receiver of ammonia just before entering the expansion valve was 133 B.tu per pound. At the compressor inlet the ammonia had vaporized and contained 643 B.tu per pound. What was the value of the refrigerating effect?

Computation:

Heat value entering expansion valve = 133 B.tu.

Heat value entering the compressor = 643 B.tu.

The refrigerating effect by definition will be then, $643 - 133 = 510$ B.tu.

Problem 2: Ammonia enters the expansion valve at 130 pounds gage with 129 B.tu and enters the compressor with 619 B.tu at 19 pounds gage. What is the refrigerating effect?

Computation:

Heat value entering expansion valve = 129 B.tu.

Heat value entering compressor = 619 B.tu.

Refrigerating effect by definition $= 619 - 129 =$ 490 B.tu.

Heat Expended in Compression

The heat expended in compression expressed in heat units or B.tu per pound of refrigerant is the heat added to the refrigerant between the point of admission to the compressor and the point of discharge from the compressor. This heat is expended to the refrigerant in raising its pressure and decreasing its volume.

Problem 1: The heat content of the refrigerant entering a compressor is 619 B.tu per pound. After compression, this value has been increased to 730 B.tu. What is the value of the heat of compression per pound of refrigerant compressed?

Computation:

$730 - 619 = 111$ B.tu per pound of refrigerant.

Coefficient of Performance

The coefficient of performance of a refrigerating machine is the ratio of the refrigerating effect to the work of compression. It is a measure of the relative amount of work done by the refrigerator to that done by the compressor.

As discussed above, the compressor and the refrigerator both add heat to the refrigerant. The thermal function of these two pieces of equipment is to get the total heat of the refrigerant from its low value at the

*University of Tennessee

expansion valve up to the high value at the condenser inlet.

The evaporator does useful work in taking up several hundred B.tu for every pound of refrigerant as it passes through the coils. The more the evaporator does, the less the compressor must do.

The coefficient of performance is, then, a measure of the ability of the equipment to get a maximum of refrigeration for a minimum of work input into the compressor.

Problem 1: The ammonia refrigerant entering the refrigerator contained 120 B.tu. It enters the compressor at 622 B.tu and leaves the compressor at 722 B.tu. Determine the coefficient of performance.

Computation:

Heat added by evaporation = 622 — 120 = 502 B.tu.
Heat added by compression = 722 — 622 = 100 B.tu.
Coefficient of performance = 502 ÷ 100 = 5.02.

Equation for coefficient of performance:

If K = Coefficient of performance
H_1 = Total heat of refrigerant just before it enters the expansion valve
H_2 = Total heat of refrigerant just before it enters the compressor
H_3 = Total heat of refrigerant just as it leaves the compressor

Then $$K = \frac{H_2 - H_1}{H_3 - H_2}$$

Problem 2: Under "standard ton" operating conditions the total heat of ammonia at the expansion valve is 128.4 B.tu. At the compressor suction it is 618.7 B.tu. At the compressor discharge it is 720.6 B.tu. Determine the coefficient of performance for ammonia refrigeration under "standard ton" conditions.

Computation:

H_1 = 128.4 B.tu.
H_2 = 618.7 B.tu.
H_3 = 720.6 B.tu.

Then $$K = \frac{618.7 - 128.4}{720.6 - 618.7} = 4.81.$$

Adiabatic Compression

Adiabatic compression is compression without the working substance either receiving or rejecting heat from external sources. While this condition seldom exists in practice, it is often desirable to make the assumption that the compression is adiabatic to make possible the more ready solution of the compression problem.

If the compression is adiabatic, the compression becomes a constant entropy thermal change and the compression cycle values are more readily traceable from available tables of properties of refrigerants.

Amount of Refrigerant Pumped per Ton of Refrigeration

The amount of refrigerant that must be pumped per ton of refrigeration per minute can be found by dividing 200 by the value of the refrigerating effect. Since the heat equivalent of a ton of refrigeration is 200 B.tu per minute, then as much refrigerant must necessarily be pumped per ton refrigeration per minute as 200 divided by the amount of heat each pound of refrigerant takes up per minute which is, by definition, the refrigerating effect.

Problem 1: The refrigerating effect of a compression system of ammonia refrigeration is 490 B.tu. How much refrigerant must be pumped per minute per ton of refrigeration?

Computation:

200 ÷ 490 = .408 pounds of ammonia.

Problem 2: The refrigerating effect of a compression system of sulphur dioxide is 143 B.tu. How much sulphur dioxide must be pumped for ten tons of refrigeration capacity per minute?

Computation:

200 ÷ 143 = 1.39 pounds sulphur dioxide required per ton of refrigeration per minute.

For ten tons it will require 10 × 1.39 or 13.9 pounds of sulphur dioxide to be circulated per minute.

Theoretical Horse Power of Compression

By previous problems, the heat value of compression per pound of refrigerant was calculated. When this value is determined and the amount of refrigerant required per ton is calculated, the remaining step, to determine the horse power of compression per ton of refrigeration, is to multiply the heat of compression per pound of refrigerant by the required amount of refrigerant needed per ton of refrigeration and divide this by the heat equivalent of one horse power, or 42.5 B.tu per minute.

Problem 1: The heat of compression of one pound of ammonia for a certain plant is 103 B.tu. The refrigerating effect is such that it is necessary to circulate 0.41 pounds of ammonia per ton of refrigeration. What is the horse power requirement per ton of refrigeration?

Computation:

.41 × 103 = 42.23 B.tu per minute.
42.23 ÷ 42.5 = .995 horse power per ton of refrigeration.

Formula for Theoretical Horse Power of Compression

By equation, the theoretical horse power required for producing a ton of refrigeration will be

$$i.hp. = M\ (H_3 - H_2) \div 42.5$$

Where $i.hp.$ = Indicated horse power per ton of refrigeration
M = Refrigerant required to make one ton of refrigeration per minute
H_3 = Total heat of one pound of refrigerant at compressor outlet pressure and temperature
H_2 = Total heat of one pound of refrigerant at suction pressure and temperature.

Problem 1: An ammonia compressor pumps 0.46

pounds of ammonia per minute per ton of refrigeration. The total heat of the refrigerant after compression was 708 B.tu. The total heat at suction was 604 B.tu. What is the horse power of compression per ton of refrigeration?

Computation:

$M = 0.46$

$H_3 = 708$ B.tu.

$H_2 = 604$ B.tu.

Then $i.hp. = .46\ [(708 - 604) \div 42.5] = 1.125$.

Relation of Coefficient of Performance to Horse Power Per Ton of Refrigeration

By above formula $i.hp. = M\ [(H_3 - H_2) \div 42.5]$.

By previous discussion M is equal to 200 divided by the refrigerating effect. Since the refrigerating effect is equal to $H_2 - H_1$, then $M = \dfrac{200}{H_2 - H_1}$.

Substituting,

$$i.hp. = \frac{200}{H_2 - H_1}\ (H_3 - H_2) \div 42.5$$

Transposing,

$$\frac{H_2 - H_1}{H_3 - H_2} \times \frac{42.5}{200} = \frac{1}{i.hp.}$$

But by definition $\dfrac{H_2 - H_1}{H_3 - H_2} = K$, the coefficient of performance

Therefore $i.hp. = \dfrac{1}{\frac{42.5}{200} K} = \dfrac{1}{0.2125\,K} = \dfrac{4.705}{K}$

Construction of Uni-Power Curves for Ammonia

By calculations and problems, the method of determining the horse power of compression has been explained. Since there are an infinite number of possible thermal and physical conditions in ammonia plant operation, there are likewise an infinite number of possible horse power requirements to produce one ton of refrigeration.

The uni-power curves presented herewith by the authors have been made on the assumption that the suction gas is dry and saturated and that the compression cycle adiabatic.

By establishing an abscissa scale of temperature in degrees Fahrenheit and an ordinate scale of pressure in pounds per square inch absolute, the saturation curve for ammonia takes the form shown in Figs. 1, 2, 3 and 4. At some other pressure and temperature above this saturation curve, points of higher heat values at the same pressures can be located. This increase of heat represents a horse power input necessary to change it to this condition above the saturation condition.

For example, a saturation suction temperature of 20 F and an adiabatic compression to 120 pounds absolute gives by computation a horse power input of 0.5 horse power per ton of refrigeration. Likewise, a suction temperature of 40 F and a discharge pressure of 172 pounds pressure absolute gives a horse power input of 0.5 horse power.

By a series of computations, sufficient values are determined for those combinations requiring 0.5 horse power input to connect these several points and give the uni-power curve of 0.5 power for the condition specified.

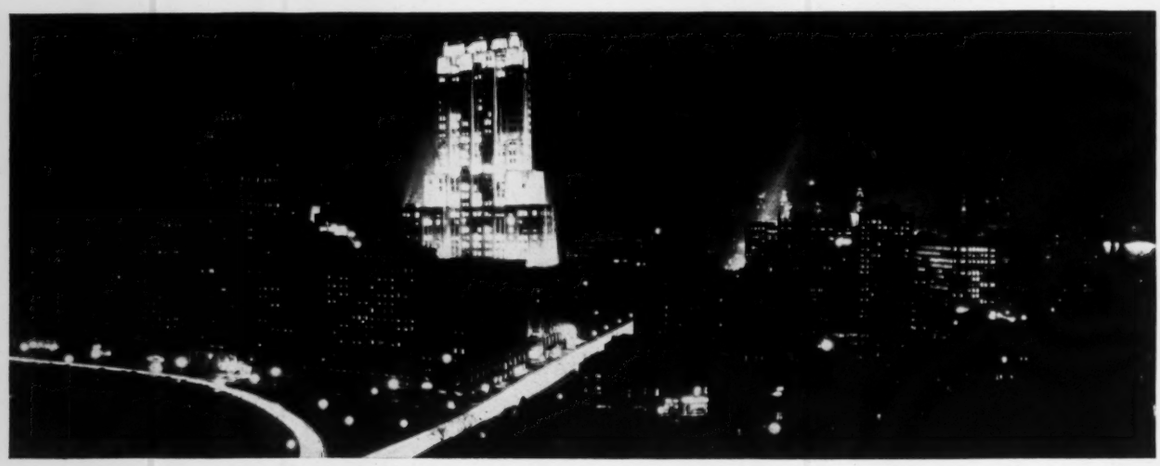
Should it be inconvenient to secure the suction temperature, the absolute suction pressure may be read off on the ordinate at the corresponding 48 pounds absolute pressure by projecting this value horizontally as indicated to the saturation curve, then vertically to the discharge pressure of 120 pounds absolute. This gives the same value as determined from the inlet temperature determination.

Similar procedure is carried on to determine sufficient values for the other curves plotted in Fig. 1, using the same general methods as outlined for the 0.5 horse power uni-power curve.

Utility of the Uni-Power Curves

Probably the most common question presented in technical refrigerating magazines is that of the horse power requirements for a given head and suction pressure, assuming dry and saturated suction gas conditions and adiabatic compression. The curves of Fig. 1 give these at a glance.

Problem: A compressor suction gage indicates 22 pounds and the discharge pressure shows 140 pounds. Under saturated suction conditions and adiabatic compression what are the theoretical horse power requirements per ton?



Computation:

22 pounds gage is equal to 36.7 pounds absolute (add 14.7 pounds to change gage pressure to absolute pressure).

140 pounds gage = 154.7 pounds absolute.

The 36.7 suction pressure on the ordinate intersects the ammonia saturation curve at 7½ F temperature.

Projecting this vertically to the 154.7 pounds pressure line by interpolation of curves, the horse power requirement per ton of refrigeration is 0.875 horse power.

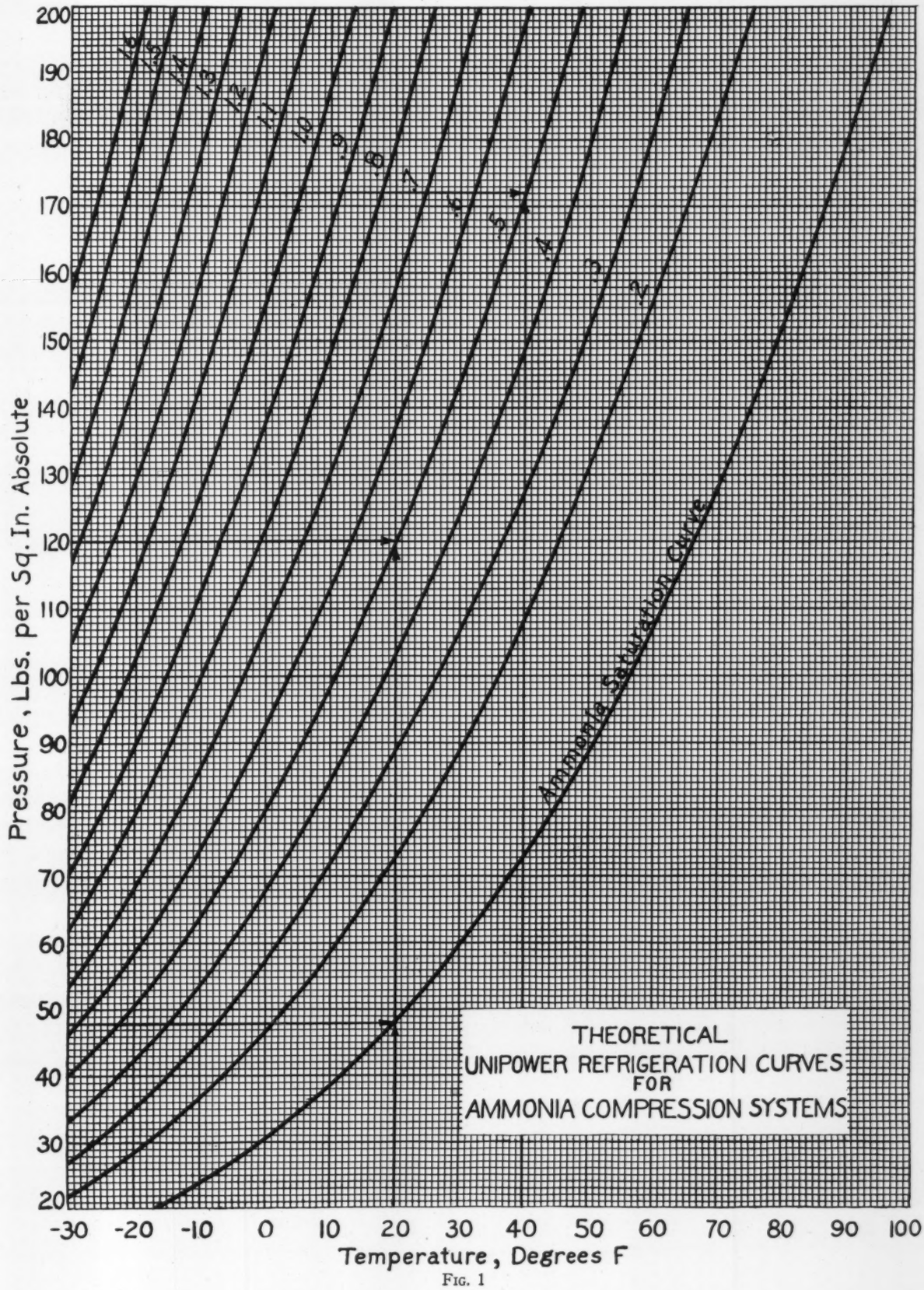


FIG. 1

Theoretical Values Corrected for Volumetric Efficiency

The capacity of all compressors is greatly reduced by failure to secure a one hundred per cent volumetric efficiency of the machine. Volumetric efficiency may be defined as the ratio of the amount that is actually discharged from the compressor cylinder to its actual cylinder displacement.

The volumetric efficiency is affected principally by:

1. Clearance of the compressor.

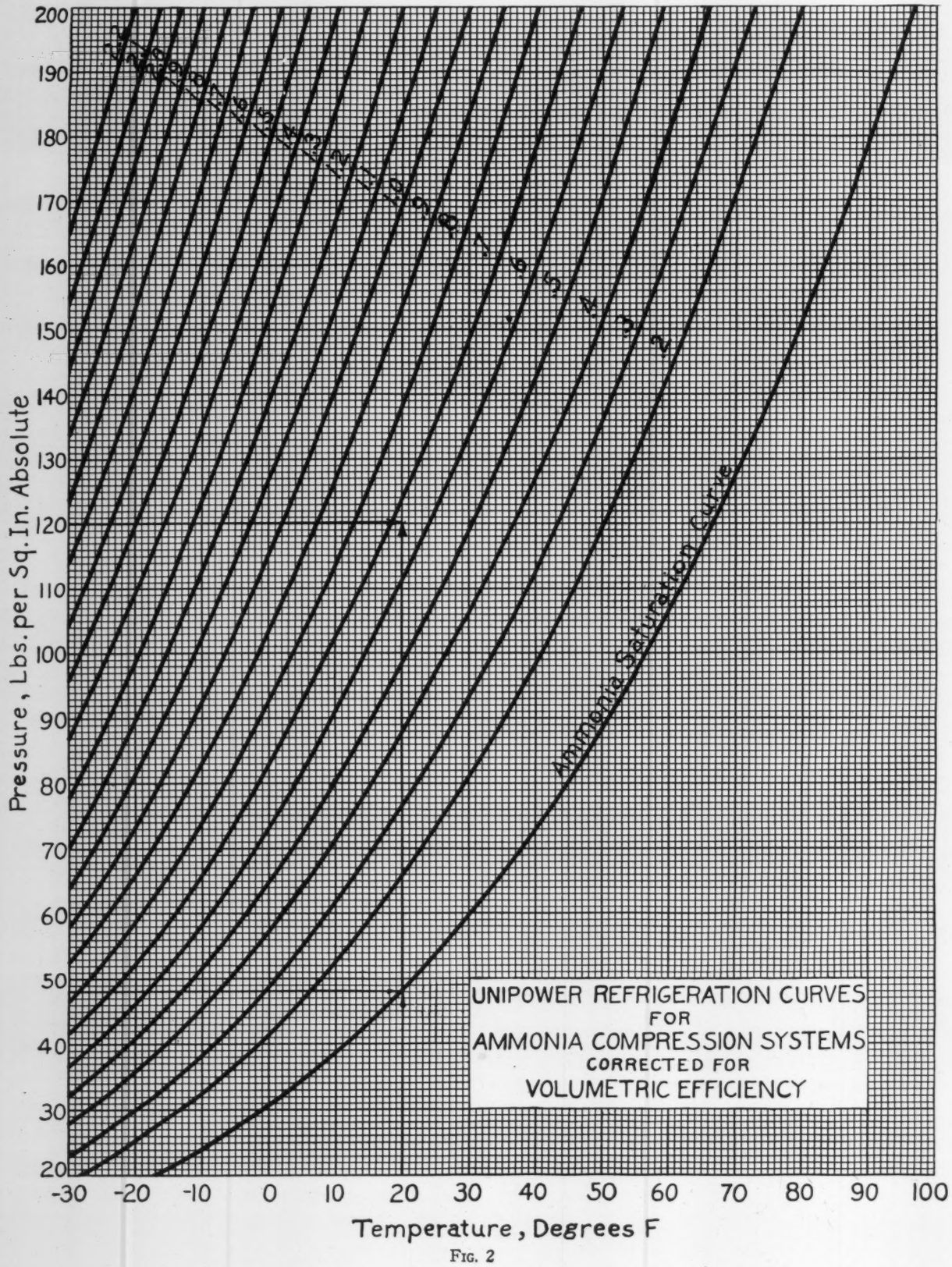


FIG. 2

2. Leakage of the piston, piston rings and valves.
3. Superheating of the gas.
4. Speed of the machine.
5. Design of the valves.

Seldom will the overall volumetric efficiency exceed 75 per cent. The values of Fig. 2 are derived from those of Fig. 1 by making this assumption. For example, consider the suction temperature of 20 F and a head

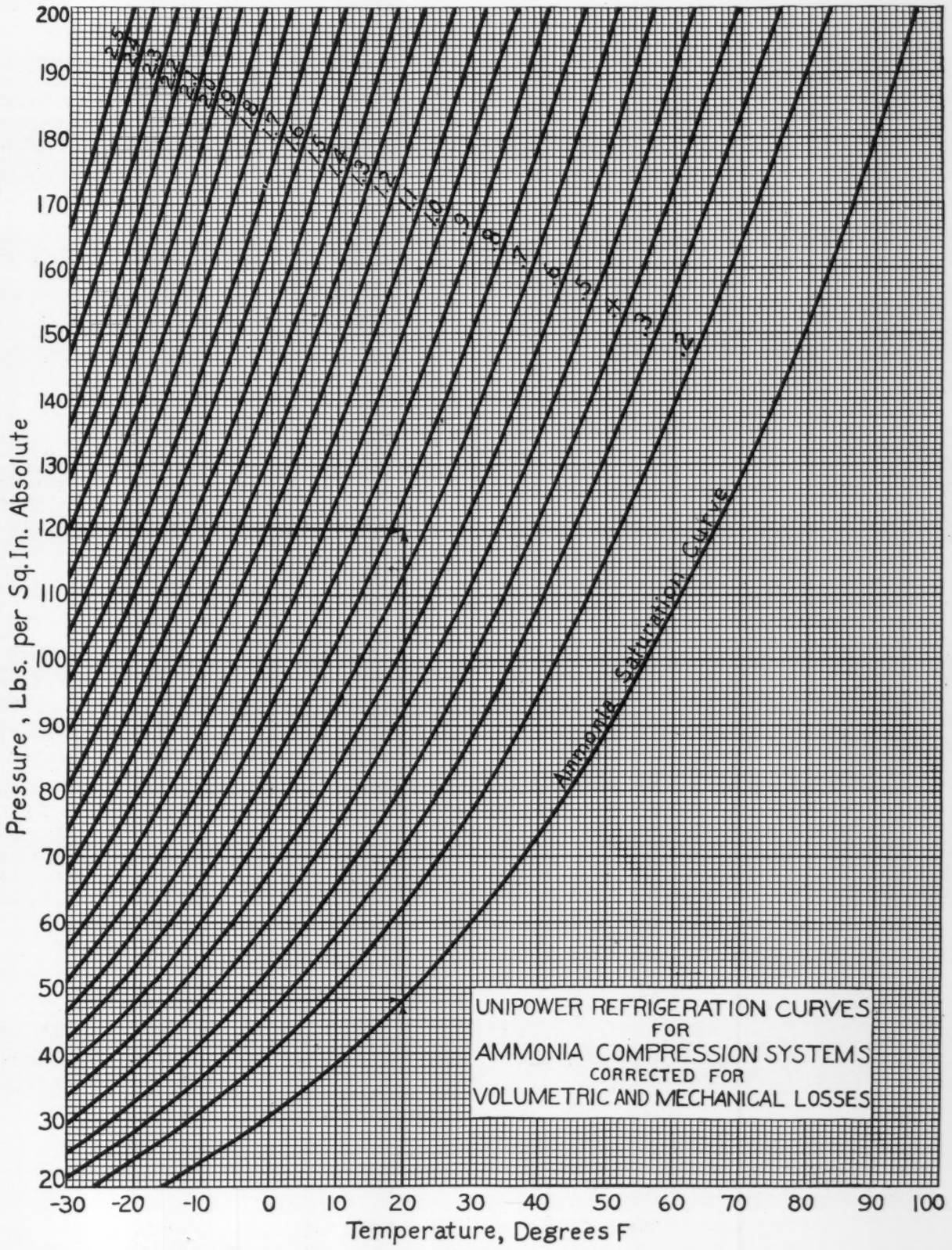


FIG. 3

pressure of 120 pounds absolute as previously determined. By checking on Fig. 2 after making correction for volumetric efficiency, the horse power requirements per ton are 0.667 as indicated by the lines shown or by computation $0.5 \div 0.75 = 0.667$.

Theoretical Values Corrected for Volumetric Efficiency and Mechanical Efficiency of the Compressor

When correction has been made for volumetric efficiency, the results obtained do not include any allow-

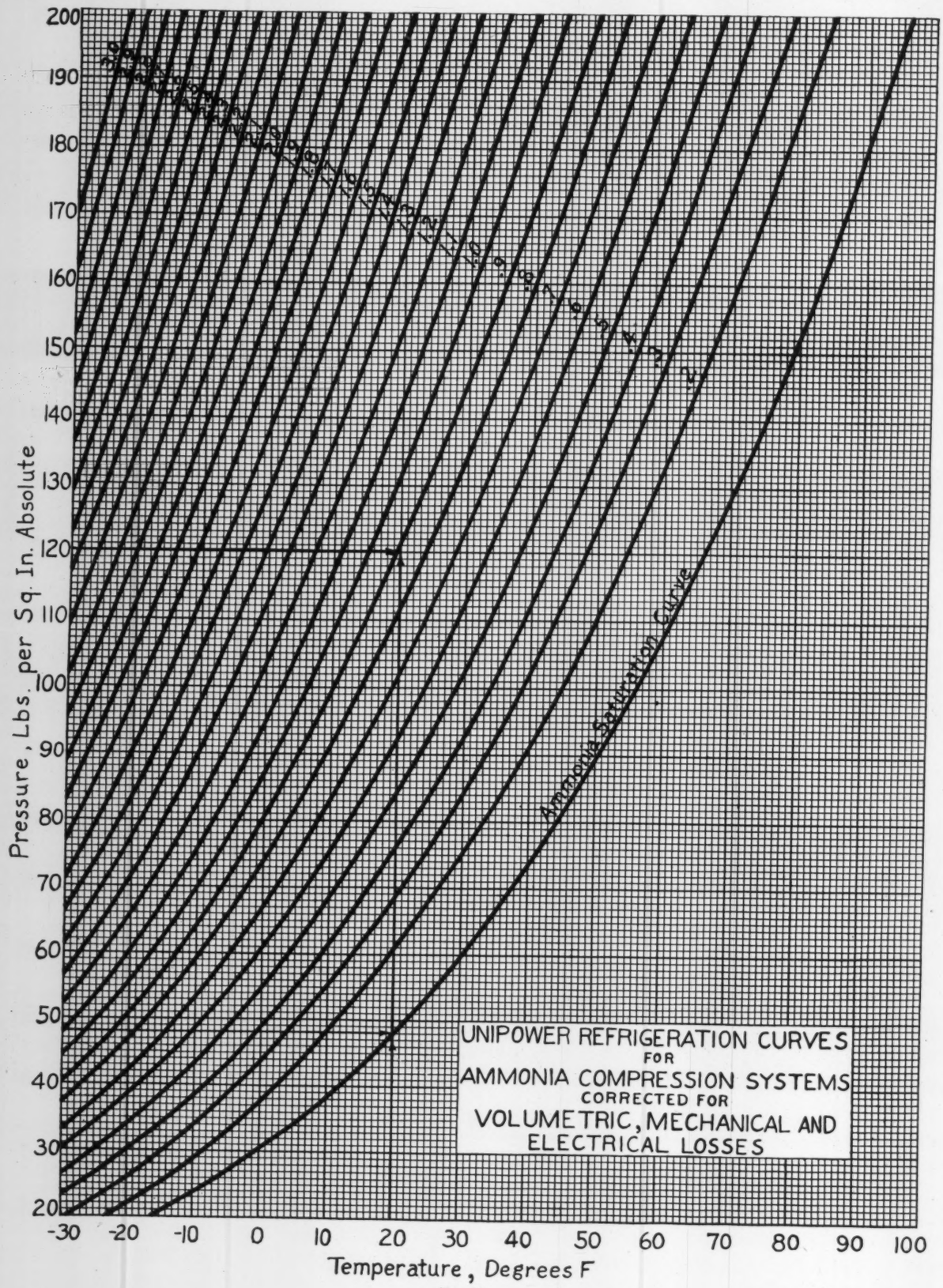


FIG. 4

ances for friction losses of the pistons, bearings, piston rods, valve mechanisms, etc. Actually, to drive the mechanism idle would require some power input, and when driving it under loaded conditions there must likewise be made sufficient allowance to overcome these friction or mechanical losses.

These losses will vary from compressor to compressor, but with good design and well-loaded conditions, the friction loss will probably approximate 12 per cent.

Fig. 3 is computed, therefore, from the values of Figs. 1 and 2 by dividing through the values of Fig. 2 by 1.00 — 0.12 or 0.88. The resultant curves will be, therefore, the uni-power curves for the actual required mechanical input per ton of refrigeration.

Following through the same suction value as before, that is, 20 F suction temperature, and then with the same discharge pressure of 120 pounds absolute, we read from the curves by interpolation a horse power input of 0.758. This is equal to the value 0.667 ÷ 0.88.

Theoretical Values Corrected for Volumetric Efficiency, Mechanical Efficiency, and Electrical Efficiency

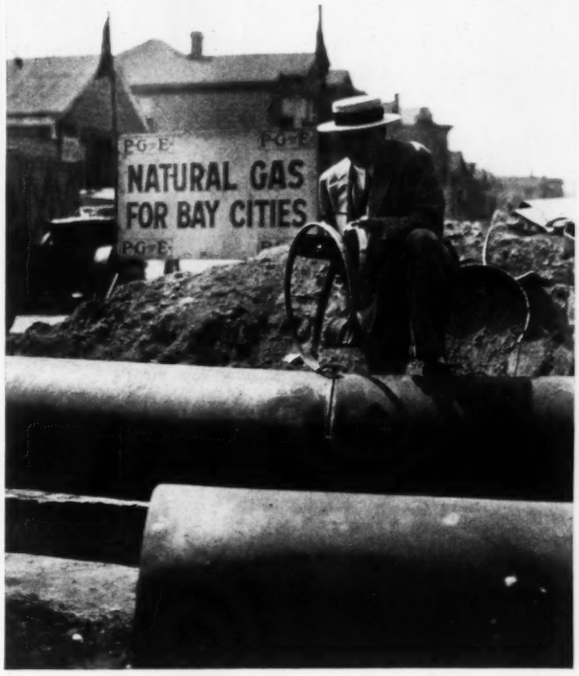
It is convenient to know just what electrical input is required per ton of refrigeration produced under different operation temperatures and pressures of suction and discharge. The average motor drive is assumed to have an efficiency of approximately 85 per cent. Fig. 4 is derived, therefore, from Fig. 3 by making allowance for this electrical motor loss of 15 per cent.

If we follow through, in Fig. 4, the values considered in Figs. 1, 2 and 3, that is, a suction temperature of 20 F and a head pressure of 120 pounds gage, the curves show by interpolation a power requirement of 0.89 hp. This is equal to 0.758 ÷ 0.85.

Templet for Bends in Large Pipe

The terminal section of a 20-in. welded natural gas line recently constructed by the Pacific Gas & Electric Co. was laid under city streets, where frequent changes in direction necessitated the use of a great many 3-piece, 45-deg. bends and 5-piece, 30-deg. bends. The usual procedure for making a miter bend requires rotating one section of the pipe 180 deg. in order to match up the ends for the bend, but a different method was developed for this job which facilitated alignment and fabrication of the numerous bends in the large diameter pipe.

A 22½-deg. gore was cut from a piece of 20-in. pipe and this became the templet. It was cut in two at the widest part and a hinge was welded to the two halves. Lug sections were welded to the two ends to aid in maintaining the proper curvature of the templet. The outside edges were beveled to facilitate marking the pipe. The center sections of the two halves of the templet were cut out to reduce the weight and handles, formed from pieces of welding rod, were welded on, as shown in the illustration.



A Templet Used in the Construction of a Welded Twenty-Inch Pipe Line Which Proved Popular with the Welders Because of Its Convenient Features

In making the cut with this templet, a section 6-in. long on the back wall of the pipe is left uncut, which aids in maintaining correct alignment. When the cut has been made and the section removed, the 6-in. uncut section in the back wall is heated with the blowpipe and the pipe is then bent around to the correct position without any lifting. A 45-deg. bend requires two cuts and welds, a 90-deg. bend four cuts and welds. Spacing between cuts is determined by construction details, but wherever possible, long radius bends were used for this large diameter pipe.

This type of templet was used during the entire construction of the line, being very popular with the welders because of its convenient features.

Testing Pressure Vessels

In welding pressure vessels in an industrial plant, a properly qualified shop inspector should be selected to see that the various details of specifications are followed constantly throughout the work. Present practice in testing welded pressure vessels requires a hammer test while under hydrostatic pressure of twice the designed working pressure. The weight of the hammer in pounds is equal to the shell thickness in tenths of an inch and the blows must be struck at 6-in. intervals on both sides of the weld.

"Open for Discussion"

A department in which we follow the custom of technical societies of allotting space in their programs for discussion of the papers presented

Steam for Jacketed Kettles

"Trap Installation for Process Work", *by T. H. Rea.* Page 108, February, 1930, issue

IN the February number of HEATING, PIPING AND AIR CONDITIONING there appears an article on "Trap Installation for Process Work," by T. H. Rea. I would like to take exception to some of his remarks.

For intermittent process work, the author speaks of introducing cold goods, liquids, etc., into a steam jacketed kettle, and states that "the demand for steam is very heavy at first and the pressure drops sharply." His curves—Fig. 3—show this.

The writer has had many years of experience in the cooking of all kinds of goods with steam, and has made many experiments, and it has been his experience that the demand for steam is twice as great after the goods are boiling as when the goods are cold. It is my experience that if a jacketed kettle is filled with cold water and the trap discharges into a tank or something, the trap discharges two or three times as often after the goods are boiling as it does when the goods were cold. —*R. L. Wells, Supt. The Masonic Temple, Chicago.*

The Author Replies

The apparent inconsistency between the correspondent's experience and the writer's statement is explained by the presence of air in the jacketed kettle which the writer assumed would be eliminated as soon as steam is turned into the kettles. However, if the trap used for draining a jacketed kettle does not have a large air handling capacity, it would take some time to remove all the air and hence the amount of steam condensed would be inversely proportional to the amount of air remaining in the kettle. Thus the steam consumption would be low at first and increase as air is eliminated. However, the greatest demand for steam when the kettle is boiling is not due to the fact that the kettle is boiling but rather because by the time the kettle does boil most of the air has been eliminated and thus more steam is in the kettle to be condensed.

Now the amount of steam condensed per square foot of condensate surface depends upon the temperature of the surface, the temperature of the steam and the conductivity of the metal used. Hence, if air can be eliminated as soon as steam is turned on so that nothing but steam is in contact with the condensing surface, the amount of condensation must necessarily be greatest when the temperature of the kettle is at its lowest point.

In actual practice we admit the maximum rate of condensation is not reached until a little time after the steam has been admitted into the kettle. However, with a trap having sufficient air-handling capacity, or if the kettle is blown down by using a bypass, this lag is of no particular consequence and the greatest amount of condensation should be reached long before the kettle is brought to a boil.

In the above letter, a statement is made that a trap discharges two or three times as often after the goods are boiling as it would when the goods were cold. This fact does not necessarily prove that there is a greater steam consumption when the goods are boiling, as there is nothing to show that the amount of condensate with each discharge is always the same. In fact, the condensation would be so great at first that a trap may discharge almost continuously, and as the temperature rises and the amount of condensate decreases, there may be more dumps in a given interval of time, but still a lot less total condensation discharges. Both upright and inverted bucket traps can discharge more water at a time than the bucket can hold, and hence the number of discharges is not a safe guide to use in estimating the amount of water discharged. A tilting or pumping trap can be used as a rough check on the amount of condensate, as no water can enter the receiving chamber after the trap starts to discharge, and thus there can be no continuous flow through a trap of this type—*T. H. Rea.*

Second Letter from Mr. Wells

In my first letter I did not intend to say one thing and mean another.

It has been my experience that the demand for steam in a jacketed kettle increases after the goods are boiling, and for this reason, when steam is first turned on, the steam effects only the contents of the kettle lying against the inner jacket and the heat transfer is very slow, owing to there being no agitation of the liquid in the kettle. But after the goods are boiling, the rapid circulation of the goods from the bottom to the top of the kettle carries away the heat more rapidly, consequently condensing more steam.—*R. L. Wells.*

Radiant and Convected Heat

Comments on the Design of Radiators, *by Malcolm Tomlinson*

THOSE who have watched the gradual change in radiator design since 1920 cannot help but be impressed with one fact. Very little advantage of a practical nature has been taken, to date, of the research data then made available by the *A. S. H. V. E.* laboratory on the radiant and convected heat output of cast iron radiators. At that time, John R. Allen proved that short types of column radiators, wall radiators and even pipe coils are quite efficient in radiant heat output. At the same time, he showed that the higher column radiators are especially suitable for heating air by convection. Later, Dr. Brabbée showed conclusively that the short column

radiators were highly efficient in keeping the temperature difference between floor and ceiling at a minimum. Actually, Dr. Brabbée proved that radiators which were highly efficient in radiant heat output were also efficient in maintaining a minimum temperature difference. This, of course, results in savings in the heat and fuel required for a given building.

In the interval mentioned, one new type of gravity radiator has appeared in this country. It consists of extended fins mounted on steam pipes. The fins and their enclosures are usually made of wrought metals such as brass and steel or iron.

The heat output of fin radiators can only be stated at present in terms of total heat. This is unfortunate, as we learned ten years ago how impossible it is to get anywhere if radiation and convection are considered together. In the first place there are no types of cast iron, or probably of fin, radiators which heat solely by radiation or convection, but the proportions of each kind of heat emitted pend on many factors. These include length, breadth or width, height, surface conditions and probably the rate of air movement over the radiator. Therefore, any variation in design is likely to vary these proportions of heat emitted. But a large proportion of the designs which are now in use, or may be used in the future, will include the radiators most efficient either in radiant or in convected heat output.

Rating of Radiators

At present there is much confusion as to the proper rating of radiators. The old method of rating by the square foot method, whether based on surface exposed or on pounds of steam condensed, gives no true picture of the radiators' comparative worth. Dr. Brabbée made this fact clear in 1926. The more recent method, of adding to the square foot rating further data on room heating effect, adds to the confusion by supplying additional information which does not help architects, contractors or owners to judge how to buy. This room heating effect is simply the temperature difference which has been obtained in a standard-sized room under certain controlled conditions. As a matter of fact, there are a number of variations not only in the so-called standard room but also in the factors which are controlled. It is therefore doubtful if the temperature differences obtained for a given radiator in one standard room would check those obtained in another.

It is likely, when the question of rating is finally settled, that a new method will be evolved. It seems probable to the writer that a rating based on the proportion of radiant and convected heat produced has considerable merit. For one thing, it separates radiators into two classes—one efficient in radiant heat output and one efficient in convection of heat. The first will always be capable of maintaining small temperature differences between floor and ceiling. The second will always be most suitable where the rate of air movement is greater than that which could be obtained by the radiator effect alone. Should such a rating be adopted, it would be of great benefit to architects and engineers in heat calculations.

In the February *Journal* of the *A. S. H. V. E.*, Konrad Meier wrote very plainly on some phases of radiator design. In his paper, he pointed out that there is a need for simplicity, economy and truth in considering the radiator situation, and he describes a type of cast iron radiator, now used in Europe, which eliminates many objections to the cast iron radiators now used in this country. This radiator which he describes is quite efficient in radiant heat output and saves space. His statements cover much ground not included in this paper, but he also stresses the need for radiators efficient from a radiant heat standpoint.

Radiator Characteristics

It has been noted that the new fin radiators are made of wrought metals. The purpose was, of course, to reduce weight. These wrought metals with their thinner sections and smoother exposed surfaces have introduced some variations in radiator characteristics. Some idea of this fact can be had from Figs. 1 to 3, on pages 660 and 661 of the December, 1929, HEATING, PIPING AND AIR CONDITIONING.

So far only designs for efficient radiant heat radiators have been considered. This type of radiator has a field which should be recognized. At the same time, where weather stripping is not used, where large temperature differences between floor and ceiling are undesirable and where moving machinery produces air currents, the convection type of radiator should, in many cases, be employed. The ideal situation, which may come with further standardization, would be to have about three sizes of each type—radiant and convected—available. To meet this need, flexibility of design is essential.

A. S. H. V. E. Code of Minimum Requirements for Heating and Ventilation of Buildings

"The Code of Minimum Requirements," ***published by the American Society of Heating and Ventilating Engineers.***

SECTION XI.—Minimum requirements for the installation of air washers and filters.

The description of various types of water-using air washers is excellent. Paragraphs 7 and 8 are unfortunate and should be rewritten to suit modern practice.

The writer of the Code evidently had in mind a picture of a two-row steel pipe tempering heater, a form practically obsolete.

The Code should limit and define just what it does mean concerning indirect heaters or convectors. If the term "Section of tempering heater" were used and defined the matter would be elucidated.

It is exceedingly important that the tempering heaters used on the cold air side of air washers shall be divided into small separately-controlled increments. The installation is fortunate which has some recirculation of the inside air to act as an automatic protection against freezing and as a stabilizer against sudden changes in temperature. With such partial recirculation, double dampers may be used to control the temperature of the air which reaches the washer.

Where all-outside air is used it is almost impossible

to use any dampers to bypass part of the cold air around the tempering heaters, since the cold bypassed air is reluctant to mix with the warmer air which comes through the heaters, and this cold air freezes the washer.

With the exceedingly rapid heat transfer which occurs with modern non-ferrous convectors, great care in design and in operation must be exercised to prevent freezing the condensation in the lower parts of the heaters themselves, and the steam supply piping must be equalized after the manner of an automobile intake-manifold to gain uniform temperatures. There must be a vacuum pump or other positive drainage which will help overcome the induced-vacuum due to condensation.

It is considered good practice to design the piping, where possible, for a higher steam supply pressure for tempering heaters than for direct radiators.

The section on air washers should be enlarged to take proper cognizance of the many kinds of dust filters, especially of the viscous type. These are effective, have long been used for the arduous service required in air-cooling electrical equipment, and are obtainable for any air-cleaning requirement of ventilating systems.

Section XII—Pumps for heating and ventilating equipment.

The section was intelligently conceived and is well carried out except for some rather obscure statements.

For instance, on page 8, the statement is made: "When the head on the delivery side of a steam driven pump exceeds 15 pounds per square inch, the condensation shall be delivered to a vented receiver located close to the level of the vacuum pump outlet. This receiver shall be connected to a separate steam or power driven pump capable of delivering against the maximum head and shall be controlled by a throttle valve, actuated by some means from the water line in the receiving tank."

One wonders why the 15-pound limitation, and why the steam driven pump limitation, and why, if a vacuum pump is being discussed, the Code does not so state.

One might revise the paragraph as follows: "When the vacuum pump is called upon to deliver the water against a considerable pressure and one beyond the practicable limits of the particular pump design, the water may be delivered to an open receiver. This tank of water may be connected to the suction side of a separate pump capable of delivering the water against the pressure (as in a high pressure boiler).

"This pump may be float-controlled by the variations in level of the water in the tank, or may be controlled by any one of several available and reliable automatic boiler-water-line governing devices."

An interesting and helpful arrangement giving an additional safety factor where automatic pumps are depended upon for feeding steam boilers operating at comparatively low pressure is obtainable as follows:

The pump discharges against a constant pressure head in a tank, which may be elevated and open, or which may be of the hydro-pneumatic type. The water flows from the tank to supply the boiler or boilers, the water-line of which is governed by an automatic regulator which controls the flow-valve to each boiler.

When the pump operates it will raise the water level in the tank, rather than flood the boilers, variations in water-volume being compensated in the tank.

It is exceedingly desirable, from an output and efficiency standpoint, that alternate flooding and starving of boilers as to their water supply shall be avoided, yet such alternations frequently occur with conventional methods of direct pump feeding.

When the pump fails to deliver water to the tank, as it may from several causes, the water level in the tank naturally will fall, and, as it nears the tank bottom, a float-controlled valve will admit an emergency water supply, as from the city mains.

Thus the boilers always are protected, as is especially necessary when gas or oil fuel is used, since these are not always put out of action when a fusible plug melts.

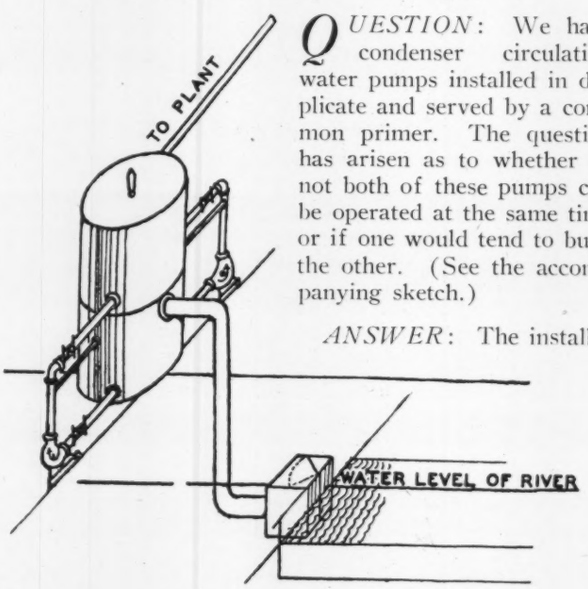
The section bears a very strong flavor of steam pump practice. It should be enlarged to include more detailed information about electric pumps, especially of the vacuum type and of the hot water circulating type.

This ends my comments of the 1929 Edition of the Code. It seems evident to me that many sections of the Code need to be revised every year to keep them up to current practice. It seems the Guide should serve as well as the Code, and that with the policy of annual Guide revision, printing of the Code might be dispensed with.—*Samuel R. Lewis.*

In the March HEATING, PIPING AND AIR CONDITIONING, *Samuel R. Lewis discussed the first three sections of the American Society of Heating and Ventilating Engineers' Code of Minimum Requirements. Mr. Lewis took up the fourth, fifth, sixth, and seventh sections of the Code in April, and in May he commented on Sections VIII-X. This month, Mr. Lewis considers Sections XI and XII.*

Appearing with Mr. Lewis' comments in the March number was a brief description of the Code of Minimum Requirements.

Condenser Pumps in Duplicate



QUESTION: We have condenser circulating water pumps installed in duplicate and served by a common primer. The question has arisen as to whether or not both of these pumps can be operated at the same time or if one would tend to buck the other. (See the accompanying sketch.)

ANSWER: The installa-

tion of condenser circulating pumps in duplicate is common practice. Since friction loss through the condenser varies approximately as the square of the quantity of water passed through, it is evident that if two pumps are operated together, both pumps will be operating against a greater head than if only one were working. So, in a measure, the pumps do work against each other. For example, in large condensers it is customary to state that each pump will be capable of passing 60,000 g.p.m. when operating alone or a total of 100,000 g.p.m. when operated together. The proportion of friction head to static head has, of course, an important influence on the amount of reduction in flow noted in the foregoing.

The effect on the action of the primer would depend upon the choice made in the original selection. The size of primer is dependent largely on the size and length of the suction pipe (both vertical and horizontal). If the primer is adequate for one pump, assuming that both pumps are started at the same time, the use of two pumps would only lower the water level in the primer a slightly greater amount due to increased friction in the suction line. It is assumed in the above that both pumps would be started and brought up to speed before opening the discharge valves.

In case one pump is operating and it is desired to start the other, the small equalizing line between pump discharge and the lower chamber of the primer permits the pump to rid itself of air and fill with water.

Unless certain factors are involved which do not appear in the question submitted, these pumps can be operated in parallel as indicated. The "bull head" nature of the discharge of the pumps is not desirable, but should not prevent the pumps from operating together in a fairly satisfactory manner.—*Arthur McCutchan.*

INTERVIEWS OF INTEREST

Dustless Removal of Dust

The Rundle Manufacturing Company, manufacturers of plumbing supplies, in their new $1,500,000 plant at Camden, N. J., have one of the best ventilated grinding departments to be seen anywhere in the United States.

The problem was a matter of hygiene—a matter of conscience on the part of owners and engineers. Iron dust is waste, but the grinding of enameled ware presents both iron and silica dust, and silicious dust in fine suspension constitutes the chief menace in dusty trades. That is why humanitarian rather than strict economic considerations have operated to install a $25,000 ventilation arrangement for a single department of this plant.

"The installation is highly special," states A. A. Wickland, the Chicago consultant who engineered this project. "The mechanical problem is simply stated. Some 3,000 pounds of silicious dust, mixed with iron, had to be removed every two hours, or about 20,000 pounds per day.

Large Ducts Leading From Work Rooms

"Dustless removal was desired because of the irritating nature of this dust, and the tendency of finer particles to remain long in suspension. Abrasive wheels are used, some large, some small, hence the great amount of ingenuity that has been devoted to the design of hoods that would intercept the tangential flow of dusts and yet not interfere with free working space. Space arrangements in the shop itself are important and the placing of machines has to be worked out to present the least possible interference with the direct flow of exhaust air currents.

Essential Features of System

"The essential features of the ventilation scheme are: (1) Two exhaust systems for forced removal of dust-impregnated air; (2) local exhaust hood at each grinding machine for the control of dust at the point of its origin; (3) piping beneath the floors, becoming larger as it approaches the central fans; (5) hydraulic dustless conveyors for receiving dust from arrester chambers and discharging it into the river."

Control of dust at its source is sought. The hoods are specially designed for as complete removal as possible. Two separate exhaust fans, with total capacity of 70,000 c.f.m., are used, and an additional booster fan provides high suction at certain points which require it.

The air from hood exhausts is immediately drawn into arrester chambers where cloth baffles trap the dust and cause it to fall. Air exhausted through the fans is clean. Trapped dust is held in arrester chambers until hydraulic removal by means of special conveyors to a river nearby.

The conveyor used for the removal of this dust is a unique feature of this design. It is literally a dustless removal of dust.

The piping is important. Galvanized piping, soldered and riveted, is used in many sizes. Pipe diameters range from 6 inches to 26 inches. Arresters

are located in the basement in front of fans, and all piping is underneath the floors. The illustration shows large ducts leading from work rooms and becoming progressively smaller from arresters to grinding machines. The smaller pipes in the left background of picture lead off from small exhausts about the shop. A dust arrester is seen in the right background.

With respect to this position of the dust chambers and the manner in which it operates to intercept the dust before it reaches the exhaust fan, one is reminded of the British official investigation of working conditions in the grinding of metals and cleaning of castings and the recommendation it carries from E. L. Macklen, engineer, and E. L. Middleton, physician, on the investigating staff for the exclusive use of manufactured grinding wheels, the strategic placement of machinery to prevent obstruction of air currents, and the development of some means of collecting dust before it passes through a fan.

General Ventilation

In addition to this dust removal system, there is a supply and exhaust system for general room ventilation. This provides against the possibility of any residual particles of dust in work-room atmospheres. Engineering attention likewise has worked out inspection methods, cleaning routines, and periodic tests of ventilation efficiencies. Also, the lighting plan, both daylighting and artificial, operates as a preventive measure in detecting dust and in obviating slow and awkward work that produces needless dust.

Photoelectric Cell for Air Pollution Studies

James E. Ives, physicist of the U. S. Public Health Service, has been closely identified with certain physical studies of city atmospheres that set new precision standards in matters of research and at the same time make it feasible for wider activities with fewer research workers.

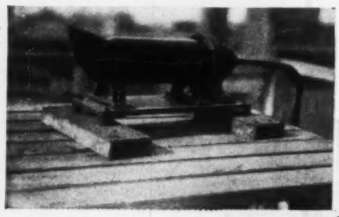
He discusses for us the importance of data gleaned from comparing continuous daylight records from downtown New York with similar records made at Hoffman Island, whose island site and isolated position make for pure air.

Dust filters out the light, and light means health. The kind of dust is important, especially when any considerable amount of the suspended foreign matter is too fine to do anything but float, and when sea fog tends to catch and hold organic dust as nuclei of moist particles in condensing vapor. The decrease of light because of fog is often as high as 25 per cent. Smoke causes greater loss.

The health of entire populations suffers through such loss of light, and this is true because the short, health-giving violet rays are filtered first. This fact is shown by readings made in New York and at Hoffman Island nine miles away. The Hudson Street address showed an average daylight loss of 42 per cent because of smoke at 8 o'clock in the morning, and a loss of 18 per cent at noon.

Mr. Ives explains for us the precision basis of these tests. The daylight recorder consists of a photoelectric cell set up in conjunction with a recording potentiometer.

The cell is in fact a mechanical eye. The light received by human eyes, transformed into nervous impulse, is transmitted to the brain. The mechanical eye is a metal-lined bulb with one clear space through which light enters and sets up electric currents which are transmitted to recording paper, so that the potentiometer makes continuous record of the light that falls upon it. The "eye" is placed high on the top of the building where no shadows can cross it. The recording instrument can be installed indoors at any point for continuous recording. The record roll is set so that each hour can be set apart for separate study, and it is on this basis that U. S. Public Health studies are made.



Showing Position of Photoelectric Cell, the Mechanical "Eye" That Records Light as Electrical Impulse

Location of Daylight Recorder on Top of the U. S. Marine Hospital at 67 Hudson Street, New York City

Recording Potentiometer Which Makes Continuous Measurement of Amount and Kind of Light That Filters Through the City's Smoke

Recording instruments are not new in atmospheric work. Similar devices in the Holland Tunnel ring a bell when carbon monoxide gas accumulates beyond the safety point, and mechanical adjustments are set to make conditions right.

Ventilation apparatus recently installed in the chambers of Congress adjusts itself on the basis of automatic records made at 16 points within the system.

At the Bureau of Standards the impulse from the photoelectric cell is amplified and made to operate a mechanism for continuous automatic temperature control.

The important factor of precision work in daylight measurement is to have continuous record and objective proof of air pollution subject to control by proper methods.—*S. P. M.*

Heating·Piping
and Air Conditioning

American Society of Heating and Ventilating Engineers
JOURNAL SECTION

JUNE 1930

Material in the Section prepared by Publication Committee: G. L. Larson, *Chairman*; H. H. Angus, and W. A. Rowe ; A. V. Hutchinson, Manager of Publications

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Surface Conductances as Affected by Air Velocity, Temperature and Character of Surface

By Frank B. Rowley[1], (*MEMBER*), A. B. Algren[2], (*NON-MEMBER*) and J. L. Blackshaw[3], (*MEMBER*), Minneapolis, Minn.

IN MAKING a complete analysis of the heat flow through built-up wall sections, that is, the flow of heat from air on one side of a wall to air on the other side, three points must be considered: *first,* the flow of heat from the air on one side of the wall to the surface on the same side, which is assumed to be the same as the flow of heat from the opposite surface to the air on its side; *second,* the conductance of the heat through those parts of the wall that are built up of homogeneous materials; *third,* the conductance of heat across air spaces within the wall. These air spaces may be of any size or shape, and there may be any number of them in the wall structure. If the laws governing these three factors are definitely known, then it is possible to calculate the heat flow through any built-up wall section, provided the characteristics of the materials used in the wall are also known.

The present investigation is part of the co-operative research program between the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS and the *University of Minnesota.* The object of the investigation was to determine the effect of air velocity, temperature, and surface characteristics on heat transmission from surfaces. Surface conductance (f) is defined as the number of British thermal units which will flow between one square foot of the surface of the material and the surrounding air per hour per degree difference in temperature between the surface and the air. A preliminary report of this investigation was published in the December 1929, A. S. H. V. E. JOURNAL. Since that time, the apparatus has been remodeled and the work has been extended to cover nine different surfaces used in building construction. In order to make this discussion clear, it will be necessary to use two of the line drawings shown in the former paper, because these drawings represent the fundamental principles of the apparatus.

One point which should be definitely understood is that these investigations cover air velocities *parallel* to the surface. The question immediately arises as to what the condition would be if the air flow were *perpendicular* or at some other angle to the surface. This is a point for further investigation; the relative surface effect of wind to different angles of the surface must be determined and factors obtained which can be applied to the various surface coefficients to correct for direction of air flow.

It was decided in this investigation to determine the coefficients with the air passing parallel to the surface. Therefore, it was necessary to construct apparatus which would provide: *first,* air moving over a test surface at various constant velocities; *second,* accurately controlled air temperatures; *third,* test surfaces which could be supplied with a measured amount of heat; *fourth,* instruments for measuring the air velocities and temperatures of the air over the test surfaces and the amount of heat flowing through the test surface. In order to obtain these conditions, the apparatus was set up as shown in the photographs, Figs. 1 and 2, and the line drawings, Figs. 3 and 4. Air of the proper temperature was supplied by a large refrigerator capable of maintaining temperatures down to —10 F. This air was blown by a 12 in. multi-blade fan, driven by a ½ hp., 850 rpm, 220 volt, d-c, direct-connected, variable speed motor. The air from the fan passed through a long, straight, 6 in. x 12 in. rectangular duct in order to eliminate eddy currents. Seventeen feet from the fan, the air passed over the 12 in. square test surface which was inserted in the side of the duct flush with its inside surface. After this, it was carried through a return bend and brought back to the cold room. This arrangement provided a flow of air past the test surface without turbulence.

The arrangement of the test surface, together with the method of measuring the air flow and the air temperatures, can be best understood by referring to Fig. 4 which is an enlarged section of Fig. 3. As shown in this drawing, the test material was placed with the test surface flush with the inside surface of the air duct. The test material varied in thickness from ¼ in. to ½ in., depending upon the type of surface. Heat for the test surface was applied by a hot plate, the quantity of heat being measured by passing it through a heat meter. The hot plate was electrically heated with 110-volt direct current, rheostat controlled, and checked with an ammeter and a voltmeter to obtain uniform heating conditions.

The meter plate, constructed of ⅛ in. Bakelite, was substantially the same as the Nicholls heat flow meter. Two parallel series of 28 pairs of 28-gage copper-constantan junctions, differentially wound on the plate, were used. Of these, one series of 56 couples served to check the other series. Surface temperatures of the meter plate were also taken with the aid of three 28-gage, copper-constantan thermocouples on either side. This meter plate was directly calibrated on the hot plate test ap-

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For presentation at the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Minneapolis, Minn., June, 1930.

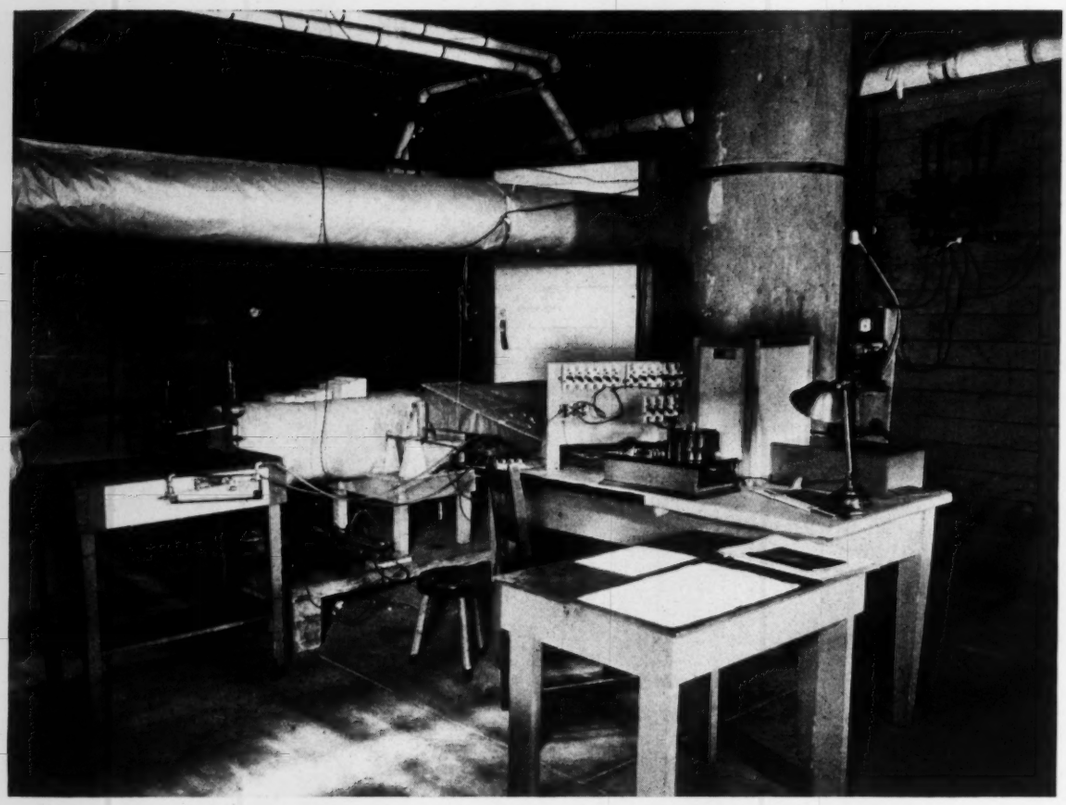


FIG. 1—FRONT VIEW OF SURFACE CONDUCTANCE TEST APPARATUS

paratus at the *University of Minnesota*. Fig. 5 shows the calibration curve for this meter. The average of the hot and cold side thermocouple readings gave the mean temperature of the meter directly in millivolts. The curve gives the corresponding number of Btu which will flow per square foot per hour per millivolt of the differential

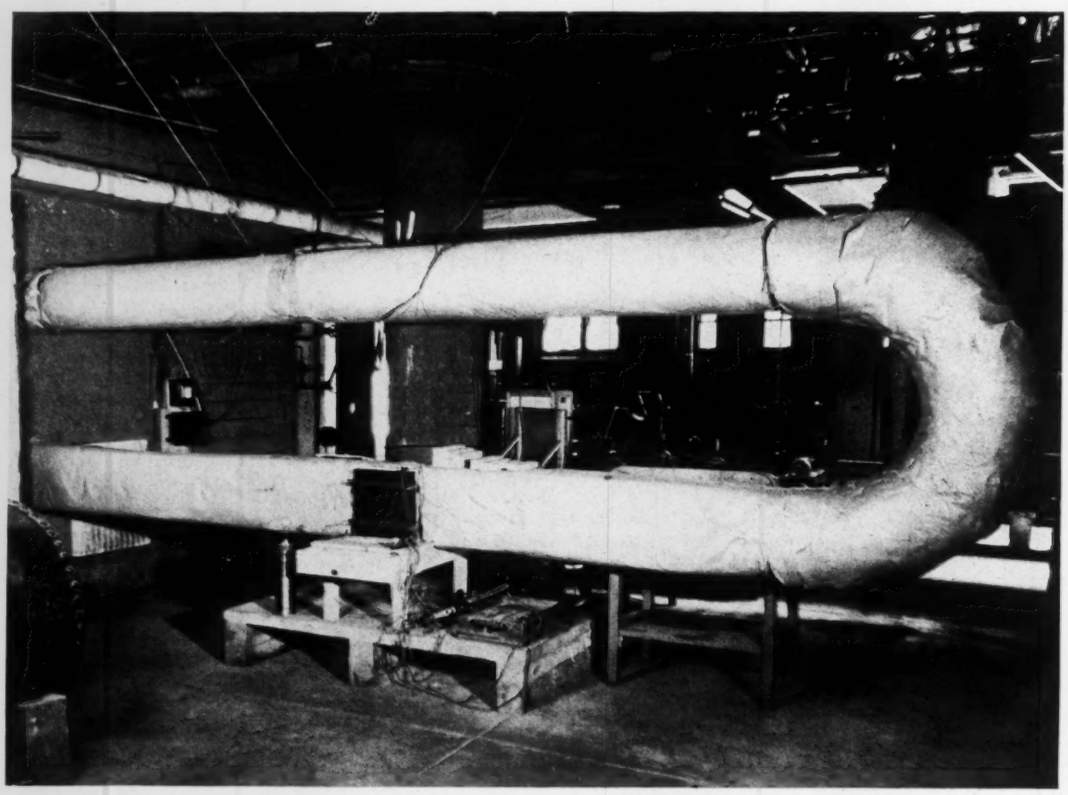


FIG. 2—REAR VIEW OF SURFACE CONDUCTANCE TEST APPARATUS

couple series. A simple multiplication of this value with the differential couple reading gives directly the number of Btu flowing through a square foot of the plate per hour. This meter plate is many times more sensitive than was the older plate used in preparing the previous report. It also has a greater conductance and, therefore, allows much more heat to flow from the test surface, thus giving a more accurate determination of the surface conductance. Two such meters were constructed, and when placed in series on the same test, their readings checked within 0.17 per cent.

The air velocity at varying distances from the test surface was measured by means of a Pitot tube and draft gage. For the lower velocities, the Wahlen gage was used, but for higher velocities, the inclined draft gage was found satisfactory. The air velocity was derived from the formula

$$V = 12.456 \times \sqrt{\frac{P_v}{w}}$$

where V = velocity of air in miles per hour

P_v = inches of water indicated as the velocity pressure by the Pitot tube

w = weight of air as obtained from tables and charts with the aid of wet- and dry-bulb thermometer readings, together with the barometric reading.

Air temperatures were measured by a 24-gage, copper-constantan search thermocouple mounted on a carriage arranged so that it could be moved in and out from the test surface and held at any determined distance. Tests were made both with a shield between the thermocouple and the test surface, and without it. It was found that, at the comparatively low temperatures used, radiation had no effect on the temperatures indicated by the couple. Therefore, most of the tests were made without this shield. All thermocouple readings were read on a potentiometer; the cold junction in all cases was an ice-bath.

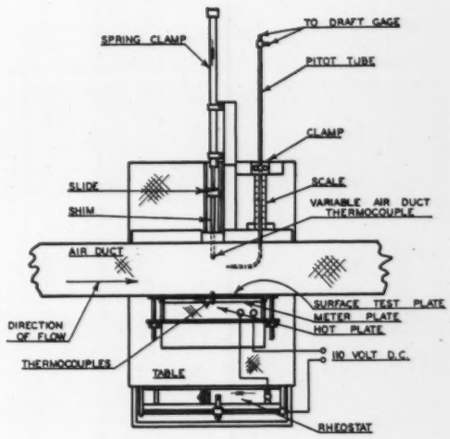


FIG. 4—PLAN VIEW SHOWING ARRANGEMENT OF METER PLATE, TEST SPECIMEN, THERMOCOUPLE AND PITOT TUBE IN RELATION TO AIR DUCT

It will readily be seen that with this set-up varying air velocities could be obtained over the test section. The velocity and temperature of the air could be accurately measured at any distance from the surface. The air temperatures were kept constant by holding a constant temperature in the refrigerating room. This was done by setting the refrigerator to give air at a slightly lower temperature than that required. The air was brought up to the required temperature by a thermostatically controlled electric heating element placed within the room. By this means, very constant temperatures could be maintained throughout any length of test period.

In order to obtain average radiation conditions, the inside surface of the test duct was painted a dull gray, and all of the pipe outside the refrigerator was covered with a one-inch thick blanket insulating material. With this arrangement, the surfaces immediately around the test surface were at substantially the same temperature

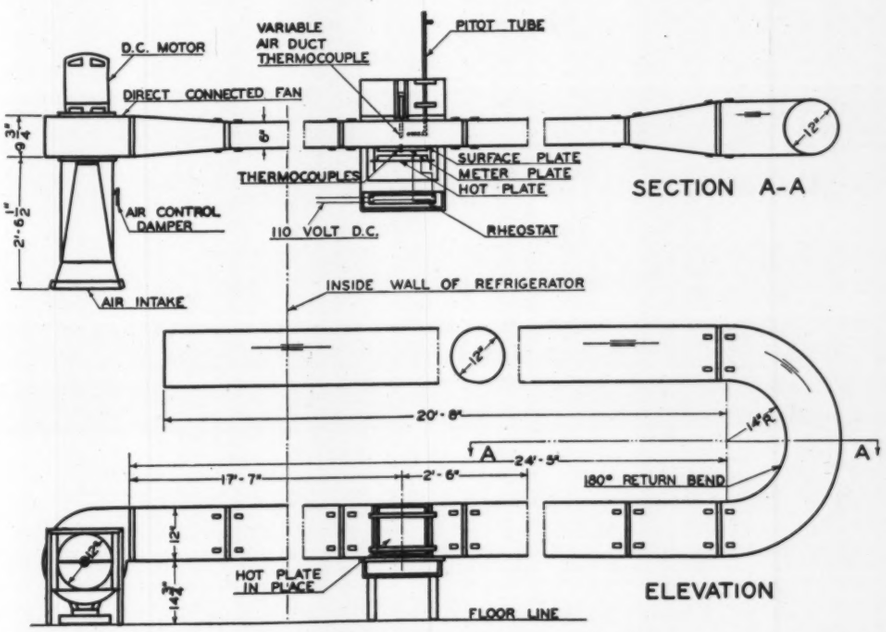


FIG. 3—PLAN AND ELEVATION OF TEST APPARATUS FOR DETERMINING SURFACE CONDUCTANCES

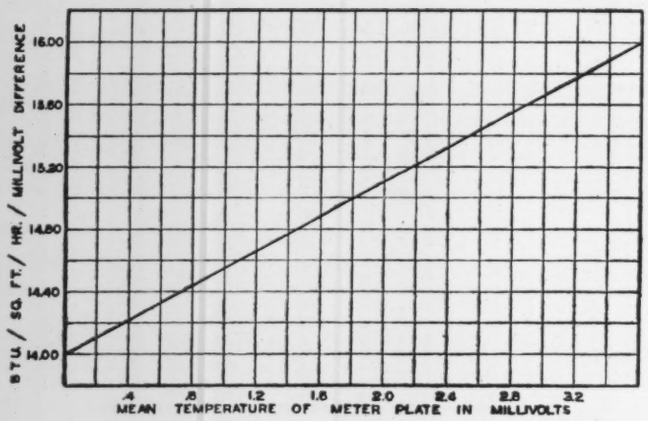


FIG. 5—CALIBRATION CURVE FOR HEAT FLOW METER

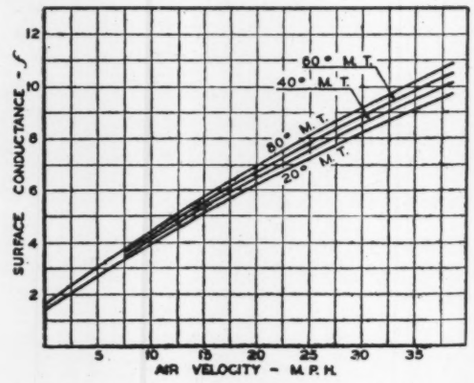


FIG. 7—CONSTANT MEAN TEMPERATURE CURVES FOR GLASS SURFACE

as the surrounding air, practically the same as that for the average wall. The insulation also prevented condensation on the outside of the air duct when low temperature air was used.

In determining the surface temperatures, two different methods were tried. *First,* the couple was embedded to bring the junction flush with the test surface; *second,* it was rigidly attached to the surface and covered with a thin vellum paper. When the thermocouple was embedded, the difference between the air temperature and the indicated surface temperature was greater than when it was placed on the surface, and, therefore, the calculated surface coefficients were somewhat lower. This difference

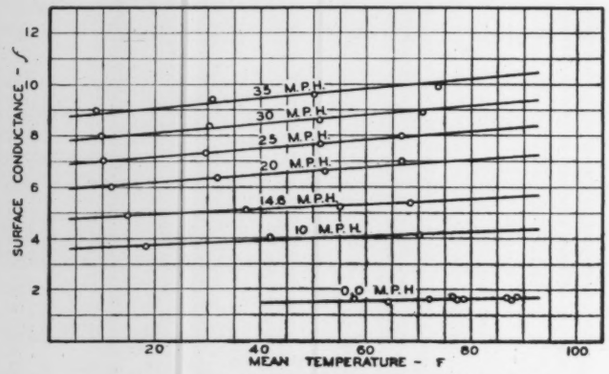


FIG. 6—CONSTANT VELOCITY CURVES FOR GLASS SURFACE

was not great, however, and seemed to be due to the fact that couples were affected by the lower and warmer material below the surface. The second method was finally selected. The surface couples were made with 28-gage copper-constantan wire flattened out at the junction, thus giving a very thin couple at the point of contact.

In the assembly of the test apparatus, the test surface, together with the heat meter and the hot plate, were placed in the side of the air duct and clamped in place with specially designed clamping screws. The conditions of air velocity, air temperature, and surface temperature were then selected, and the apparatus was operated under these conditions for a sufficient length of time to assure uniform results. The air velocity for the test was measured at the center of the duct, because this would be the maximum air velocity over the test surface. The air temperature was measured by placing the search thermocouple one inch from the test surface. Preliminary tests had shown that when the thermocouple was placed in contact with the test surface and gradually moved away from it, the temperature steadily dropped until the couple was about ½-in. from the surface, after which this temperature remained uniform and equal to the air temperature, regardless of distance. One inch distance was therefore taken to be reasonable, and was maintained throughout all tests.

The obtaining of an accurate test necessitated the holding of constant conditions over a considerable length of time. Data for a test were not taken until preliminary observations, taken at fifteen minute intervals, showed that the heat flow, room, surface, and air temperatures, and air velocity were constant. These readings took three or four hours between tests. A test consisted of recording the following data:

1. Type of surface.
2. Test number, date, time, name of observer.
3. Barometric reading, wet- and dry-bulb temperatures.
4. Voltage on blower-fan and inlet damper-setting.
5. If Wahlen gage were used, air temperature to determine the specific gravity of the alcohol in the gage.
6. Pitot tube readings at distances varying from 0.125 in. to 3 in. from the test surface.
7. Differential, hot, and cold meter plate readings.

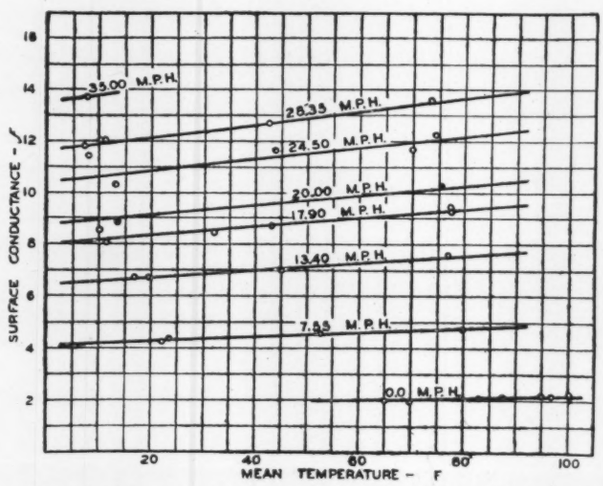


FIG. 8—CONSTANT VELOCITY CURVES FOR BRICK SURFACE

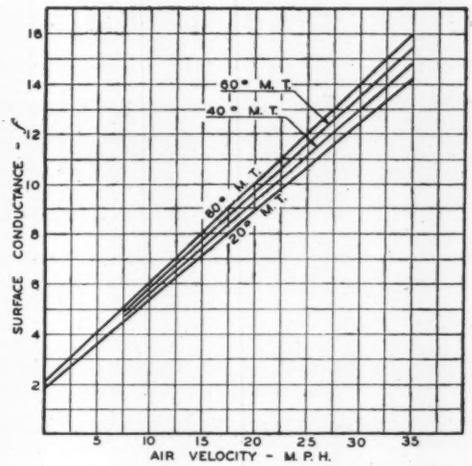


FIG. 9—CONSTANT MEAN TEMPERATURE CURVES FOR BRICK SURFACE

8. Hot plate voltage and amperage.
9. Surface temperature.
10. Air temperatures at distances from the surface varying from 0.1 in. to 3 in.

Because all temperatures were taken at or near the center of the meter plate and the test surface, and because the meter plate and the test surface were very thin, no allowance was made for end loss of heat from these plates. As an additional precaution, the edges of these plates were insulated with heavy layers of felt to stop any heat loss. Mean temperatures for a test were taken as the average between the air temperature and the surface temperature of the test specimen.

Values of the surface conductance for each test were obtained by dividing the total heat leaving the test surface per square foot per hour by the temperature difference between the surface and the air one inch away from the surface. Values of the surface conductance of any one surface vary with the mean temperature and the air velocity. Keeping one of these two variables constant, a series of tests were made to determine the effect of the other and the results were plotted in the form of a curve.

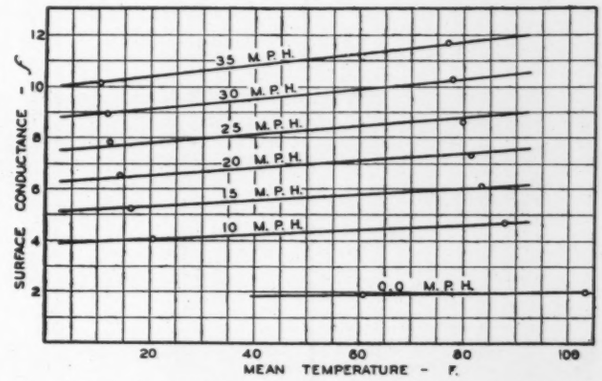


FIG. 12—CONSTANT VELOCITY CURVES FOR SMOOTH PLASTER SURFACE

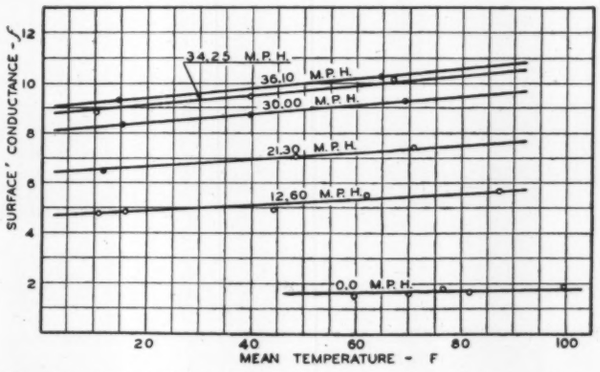


FIG. 10—CONSTANT VELOCITY CURVES FOR WHITE PAINT SURFACE ON PINE

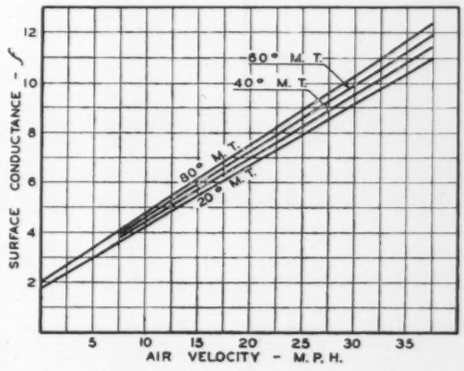


FIG. 13—CONSTANT MEAN TEMPERATURE CURVES FOR SMOOTH PLASTER SURFACE

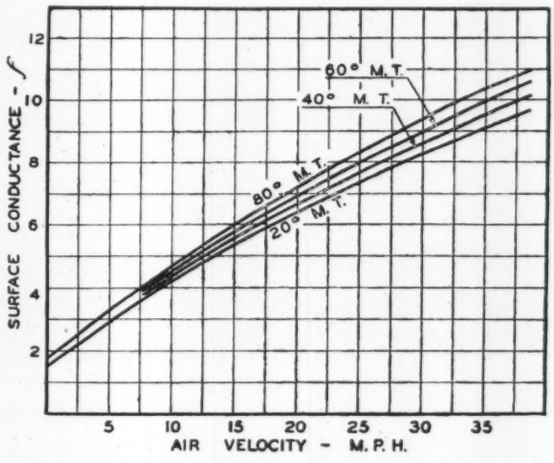


FIG. 11—CONSTANT MEAN TEMPERATURE CURVE FOR WHITE PAINT SURFACE ON PINE

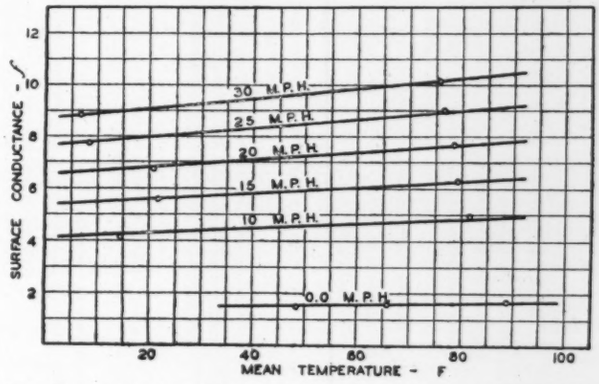


FIG. 14—CONSTANT VELOCITY CURVES FOR CLEAR PINE SURFACE

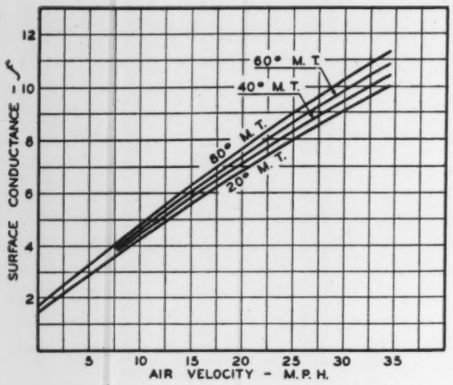


FIG. 15—CONSTANT MEAN TEMPERATURE CURVES FOR CLEAR PINE SURFACE

Surfaces which were considered to be most typical of building construction were used for these tests. In making tests on each surface, several different air velocities were selected and runs were made at different mean temperatures for each velocity. The following surfaces were tested: glass, brick, white paint on pine, smooth plaster, clear white pine, rough plaster, concrete, and stucco. Very complete tests were made on the first three of these surfaces, four or more points being taken for each respective air velocity at different mean temperatures ranging from zero to 100 F. It was found that these points lay practically on a straight line and that when they were plotted on a large scale graph and the lines were extended, these lines crossed the line of zero surface conductance at absolute zero mean temperature, or, in other words, that with total absence of heat, the surface conductance was zero. This was true of all surfaces tested.

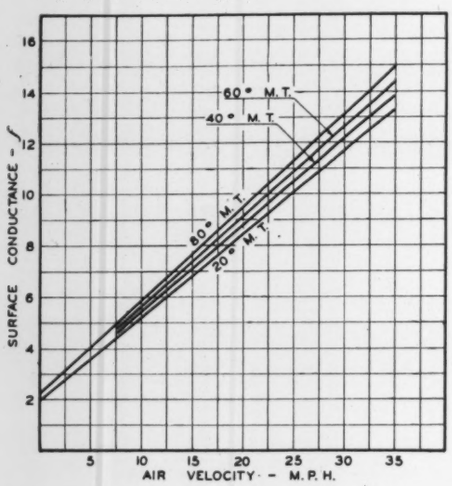


FIG. 17—CONSTANT MEAN TEMPERATURE CURVES FOR CONCRETE SURFACE

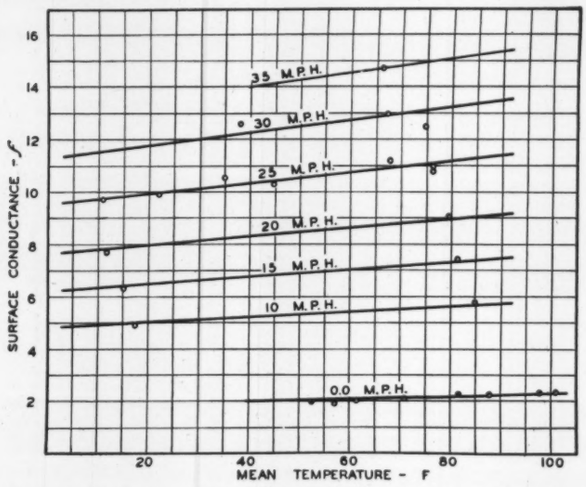


FIG. 16—CONSTANT VELOCITY CURVES FOR CONCRETE SURFACE

As representative of a typical test, the complete data taken for smooth plaster are shown in Table 1. Final results for all of the tests are shown in Figs. 6 to 22, inclusive.

Figs. 6 and 7 give data obtained on the glass surface, tests having been made at air velocities ranging from zero to 35 miles per hour. Fig. 6 shows the relation between surface conductance and mean temperature at certain constant velocities. The constant mean temperature curves for glass, Fig. 7, were derived from the curves shown in Fig. 6. Reading up the 20 F mean temperature line of Fig. 6, points representing surface con-

TABLE 1—TEST DATA FOR SMOOTH PLASTER SURFACE

Item No.	Test No.	Air Velocity M.P.H.	Meter Plate Temperatures Millivolts				Air and Surface Temperatures Degrees Fahrenheit				Heat Flow Btu/Sq. Ft./Hr.	Surface Conductance f
			Differential	Hot Side of Meter	Cold Side of Meter	M. T. of Meter	Test Surface	Air Temp. 1 In. From Test Surface	M. T.	Temp. Difference		
1	252	35.00	10.324	1.018	0.629	0.823	17.55	2.85	10.20	14.70	149.233	10.152
2	251	30.00	10.538	1.090	0.696	0.893	20.20	3.05	11.62	17.15	152.748	8.906
3	253	25.00	10.402	1.102	0.715	0.908	21.75	2.45	12.10	19.30	150.829	7.815
4	254	20.00	10.507	1.202	0.803	1.002	25.70	2.35	14.02	23.35	152.929	6.549
5	255	15.00	10.504	1.302	0.907	1.104	31.00	1.55	16.27	29.45	153.463	5.211
6	256	10.00	10.384	1.440	1.053	1.246	39.25	1.90	20.57	37.35	152.540	4.084
7	257	0.0	6.584	2.008	1.759	1.883	86.45	34.85	60.65	51.60	99.089	1.920
8	258	35.00	9.746	2.363	1.993	2.178	83.25	70.60	76.92	12.65	148.285	11.722
9	259	30.00	9.790	2.399	2.028	2.213	84.95	70.50	77.72	14.45	149.150	10.322
10	260	25.00	9.852	2.474	2.103	2.288	88.45	71.05	79.75	17.40	150.489	8.648
11	261	20.00	9.795	2.524	2.157	2.340	91.50	71.25	81.38	20.25	149.863	7.400
12	262	15.00	9.777	2.600	2.245	2.422	95.60	71.30	83.45	24.30	150.028	6.173
13	263	10.00	9.550	2.735	2.392	2.563	103.40	72.30	87.85	31.10	147.308	4.737
14	264	0.0	5.970	2.823	2.603	2.713	126.15	80.35	103.25	45.80	92.594	2.022

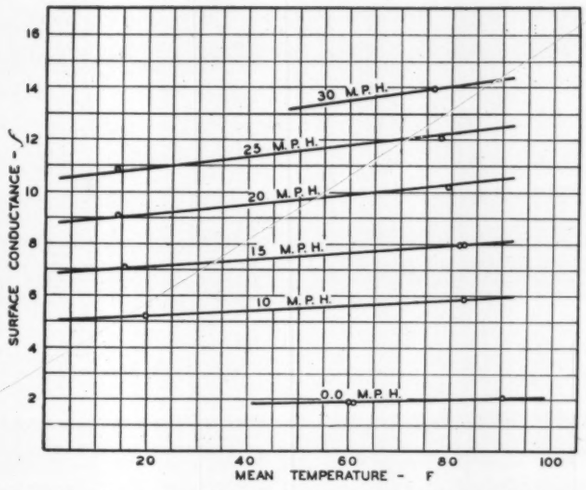


FIG. 18—CONSTANT VELOCITY CURVES FOR ROUGH PLASTER SURFACE

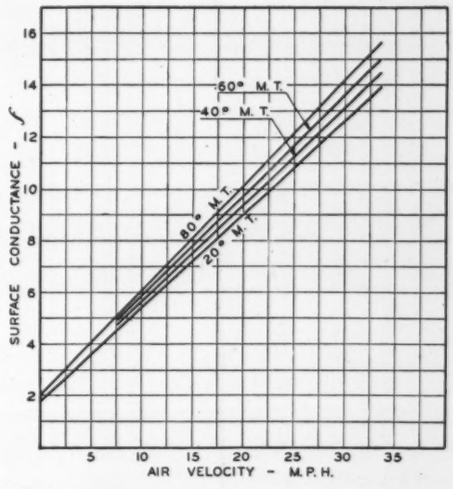


FIG. 19—CONSTANT MEAN TEMPERATURE CURVES FOR ROUGH PLASTER SURFACE

ductances were read on each of the air velocity curves. These points were then plotted against air velocity on the graph shown in Fig. 7 to give the 20 F mean temperature curve. The 40 F, 60 F, and 80 F curves were obtained in like manner. Other mean temperature curves might have been obtained for any limits within the curve of Fig. 6, or for limits outside of the curve by extending the constant velocity lines. Other values can be interpolated directly from the curve sheet, Fig. 7. Eddy currents and turbulent air flow prevented tests from being taken at velocities greater than 35 miles per hour. Rough surfaces caused more difficulty at high velocities than smooth ones.

The curves in Fig. 8 to 21, inclusive, need no specific explanation. They represent different surfaces tested and are similar to the curves in Fig. 6 and 7.

The curves in Fig. 22 show the surface conductance for each of the materials tested at a mean temperature of 20 F. This mean temperature was selected as representative of average wall conditions. From this group of curves, it is evident that materials may be placed in groups according to their surface characteristics. The curves for glass and white paint on pine coincide, and curves for similar surfaces would, no doubt, fall close to this line. The curves for clear pine and smooth plaster are substantially the same, and it is assumed that curves

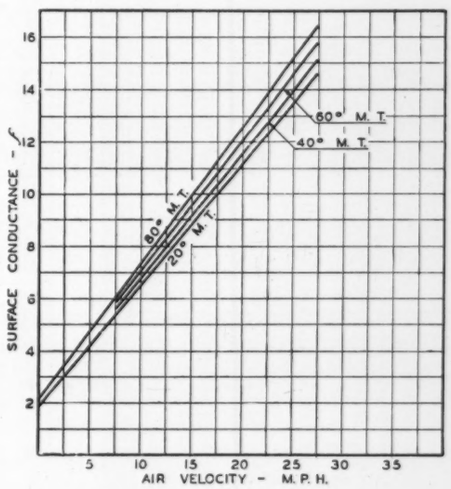


FIG. 21—CONSTANT MEAN TEMPERATURE CURVES FOR STUCCO SURFACE

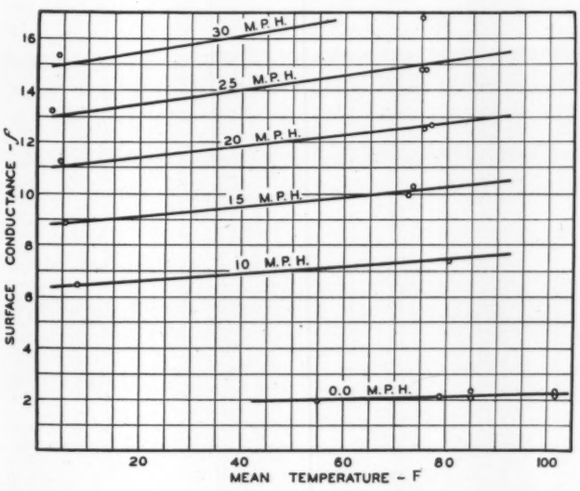


FIG. 20—CONSTANT VELOCITY CURVES FOR STUCCO SURFACE

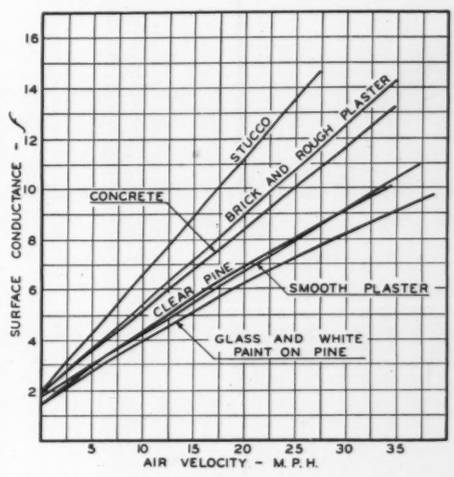


FIG. 22—CURVES SHOWING RELATION BETWEEN SURFACE CONDUCTANCES FOR DIFFERENT SURFACES AT A MEAN TEMPERATURE OF 20 F

of other smooth wood surfaces would correspond to them. Brick and rough plaster show identical results, and the concrete surface curve lies but slightly below them probably because the concrete surface was smoother than either the brick or plaster. The stucco surface was very rough and irregular. It is difficult to determine the coefficients for such surfaces, and there would doubtless be a variation depending upon the surface irregularity. Tests were also made on a sand-coated surface painted white, but no curve sheets are included for these tests. Results of this surface, if plotted on Fig. 22, would have placed a curve slightly below that for concrete. For all surfaces tested, the surface conductances at zero air velocity fall between 1.4 and 2.0. While these values were recorded as zero velocities, it is understood that zero velocity is impossible to attain with vertical surfaces because of convection currents.

Whether or not humidity affects surface conductance is a point to be considered. If it does, the effect is of small consequence because, although there was no provision made for keeping constant humidities in these tests, there was no appreciable variance in the results. The effect of a wet surface on the surface coefficients is also a question for further consideration.

It is significant that the results of the tests showing surface coefficients at zero velocity check closely with those which were obtained in former tests on similar materials, using the hot box set-up for built-up wall section tests at the *University of Minnesota*, which set-up does not allow for any movement of air.

Brooklyn Polytechnic Anniversary Dinner

Polytechnic Institute of Brooklyn will celebrate the completion of its seventy-fifth year on June 17th and 18th. An anniversary dinner under the auspices of the Corporation, Faculty, and Alumni will be held at the St. George Hotel in Brooklyn on the evening of the 17th. Among the speakers will be Walter Hampden, Polytechnic 1900; Dr. Frank Graves, Commissioner of Education of the State of New York, and Professor Karl Compton of Princeton University, President-elect of the Massachusetts Institute of Technology.

The seventy-fifth annual commencement will be held on June 18, 1930, with Dr. Graves as commencement speaker. First honorary degrees in the history of the Institute will be conferred on Admiral Richard E. Byrd and Professor Karl Compton. Polytechnic Institute of Brooklyn is one of the oldest American colleges of Engineering and is a pioneer in the establishment of college grade evening courses leading to the degree.

Proposed Standard Smoke Ordinance

In view of the importance of the smoke problem in American cities, the U. S. Bureau of Mines has reprinted the "Proposed Standard Smoke Ordinance" which was prepared by a joint committee comprised of representatives of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, the *Stoker Manufacturers' Association*, the *American Civic Association*, and the Fuels Division of the *American Society of Mechanical Engineers*, and which was originally printed in *Mechanical Engineering* for May, 1924. Copies of this reprint, designated as Information Circular 6262, may be obtained from the U. S. Bureau of Mines, Washington, D. C.

Loss in Coking Quality of Coal Due to Exposure

As a general rule, coals initially high in oxygen absorb more oxygen readily, and if they initially possess coking qualities the coking strength is reduced upon exposure in storage. Such changes are particularly pronounced with high-oxygen coals which are near the border line between coking and non-coking coals.

The Northwest Experiment Station of the U. S. Bureau of Mines, Seattle, Washington, in co-operation with the University of Washington, has just completed and published the results of a study of the loss in agglutinating power of three coals of this character upon exposure. All three of the coals contained such high percentages of oxygen that they would not ordinarily be considered acceptable for the manufacture of blast-furnace coke, though all of them are being so used. Each coal was ground to pass 40-mesh size and exposed in a thin layer for several months in the laboratory. Coal of this rank is so susceptible to deterioration in coking quality that it is possible to follow the loss in agglutinating power at ordinary temperatures in comparatively short periods of time, whereas with the higher rank Eastern coking coals it is necessary to use elevated temperatures to accelerate the deterioration. The loss in coking property was determined at intervals by means of the Marshall-Bird agglutinating test.

Two of the coals showed a drop in agglutinating value from approximately 3,500 to 850 during the first two months. After this period the loss in agglutinating value was at a much slower rate. The other coal, which had an agglutinating value of 3,700 originally, dropped to 2,800 in one month and to 2,500 in two months. Ultimate and proximate analyses were made of each coal before and after the test period. The most significant change noted was the increase in oxygen content after exposure.

Burning of Small Particles of Carbon

A large amount of information on the manner in which small particles of carbon burn has been obtained as the result of tests conducted at the Pittsburgh Experiment Station of the U. S. Bureau of Mines, Department of Commerce. It has been found possible, by a novel method, to determine accurately the rate at which such particles of different sizes burn in air at different particle surface temperatures and at a wide variety of air velocities. In all cases the specific-surface reaction rate increases with increasing particle surface temperature. This temperature coefficient is enormously larger for the smaller particles than for the larger particles. Also, the specific-surface reaction rate is much larger for the smaller particles than for the larger particles. The rate, of course, increases with increasing air velocity. The results are of especial interest in connection with the design and operation of furnaces burning powdered fuel.

Air Infiltration Through Various Types of Wood Frame Construction

By G. L. Larson[1], D. W. Nelson[2] and C. Braatz[3], Madison, Wis.
MEMBERS

Introduction

FOR the past three years, a program of cooperative research has been under way sponsored by the *University of Wisconsin* and the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS for the purpose of determining the relative air tightness of various types of building construction. The initial work of this program was confined to brick wall construction, the results of which were presented in a paper entitled, Air Infiltration Through Various Types of Brick Wall Construction, at the Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, January, 1930.

In the Summer of 1929, work was begun on a series of tests pertaining primarily to wood frame construction under a cooperative agreement between the Society, the University and the *National Lumber Manufacturers' Association*. It is the results of the latter program with which this paper is concerned.

Description of Test Apparatus

The test apparatus shown in Fig. 1 consists briefly of the pressure chamber *A*, and the collecting chamber *B*, between which the panel to be tested is secured by means of *C*-clamps. Air tight seals are obtained between the two sides of the panel frame and chambers *A* and *B* by means of a sponge rubber gasket attached to the perimeter of the chamber openings. Artificial wind pressure is produced by a small motor-driven blower, shown at the extreme left of Fig. 1. The blower is in communication with the pressure chamber through an adjustable damper *E* by means of which the pressure drop through the wall is controlled. Other control dampers are provided at *D* and on the intake to the blower itself. The pressure difference in chambers *A* and *B*, which is the pressure drop through the wall panel, is measured with an inclined draft gage, *F*.

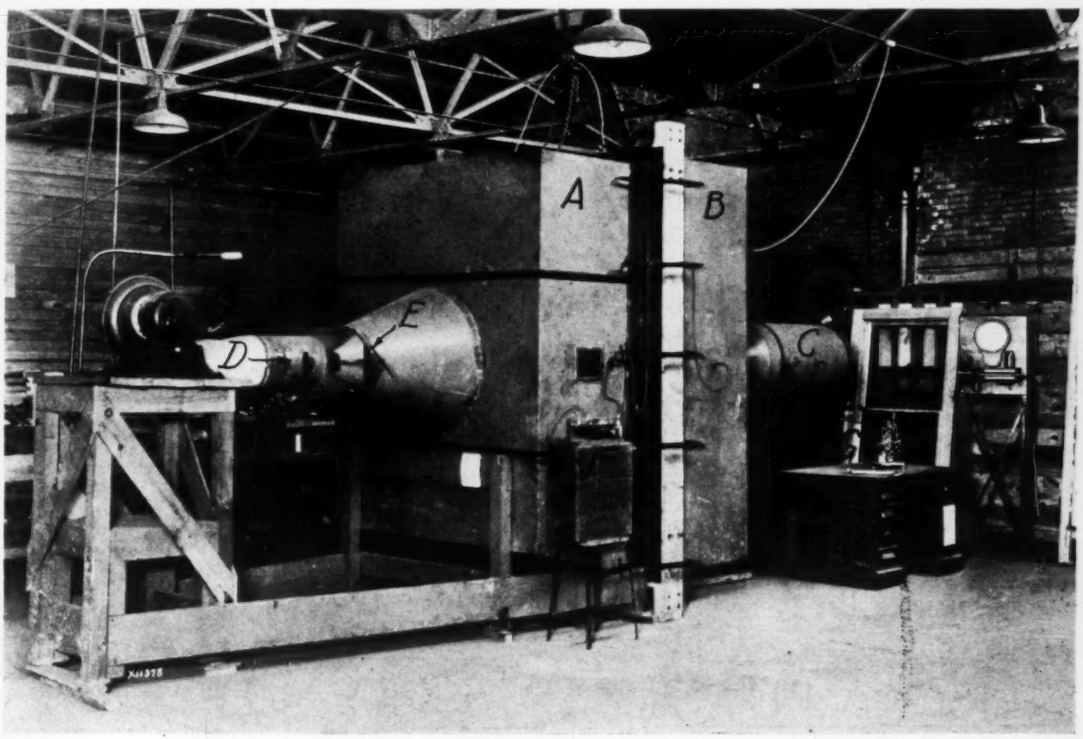


FIG. 1—GENERAL LAY-OUT OF TEST EQUIPMENT

The amount of air passing through a wall panel is measured by a set of interchangeable orifices ranging in size from ⅜ in. to 6 in. in diameter, mounted on the end of orifice box *C*. The pressure drop through the orifice is determined by a Wahlen gage, *G*. To facilitate examination of a wall panel after it has been clamped

[1] Chairman, Dept. of Mechanical Engineering, University of Wisconsin.
[2] Assistant Professor of Steam and Gas Engineering, University of Wisconsin.
[3] Instructor of Steam and Gas Engineering, University of Wisconsin.
For presentation at the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Minneapolis, Minn., June 1930.

TABLE 1—DESCRIPTION OF TEST PANELS AND SUMMARY OF RESULTS OF AIR INFILTRATION TESTS

Panel No.	Description of Construction				Standing Period in Days	Air Infiltration in Cu. Ft. Per Hour Per Sq. Ft. of Wall — Wind Velocity—Miles Per Hr.						Panel No.	Index	
	Outside Construction			Inside Construction		5	10	15	20	25	30		To Figures	To Spec.
	Sheathing	Bldg. Paper	Siding											
1A	1x6 Green Dressed and Side Matched No. 1 Common	None	None	None	29	16.3	47.0	81.2	115.0	149.9	188.0	1A	4	3
1A1	As in 1A except knot hole plugged	None	None	None	29	16.3	46.5	78.6	111.8	145.8	182.0	1A1	16	3
1B	1x6 Air Dried Butt-Edged No. 1 Common	Bldg. Paper B.	1x10 Bevel Siding Air Dried	None	70	0.04	0.13	0.28	0.45	0.62	0.78	1B	20	22
1B1	As in 1B	As in 1B	Paint Added to Siding in 1B	None	6	0.03	0.10	0.18	0.27	0.35	0.43	1B1	20, 22	22
1C	As in 1B	As in 1B	As in 1B1	Wood Lath and 3 Coats Gyp. Plaster	68	0.03	0.09	0.16	0.23	0.29	0.33	1C	22, 24	23
1D	1x6 Air Dried Dressed and Side Matched No. 1 Common	None	¾x2 Expanded Metal 1⅛ in.—3 Coats Stucco	None	29	0.02	0.05	0.08	0.12	0.14	0.15	1D	25	15
2A	1x6 Air Dried Dressed and Side Matched No. 1 Common	None	None	None	28	2.4	8.0	15.3	23.3	32.5	42.3	2A	5,–16, 25	4
2B	As in 2A	Bldg. Paper A.	1x6 Drop Siding Air Dried	None	14	0.04	0.13	0.28	0.45	0.62	0.78	2B	7,–20, 21	6
2B1	As in 2A	As in 2B	Paint Added to Siding in 2B	None	6	0.03	0.12	0.27	0.43	0.59	0.75	2B1	20	6
3A	1x6 Air Dried Dressed and Side Matched No. 1 Common	None	None	None	28	1.3	4.6	9.3	15.1	21.5	28.8	3A	6,–16, 25	4
3B	As in 3A	Bldg. Paper A.	1x6 Bevel Siding Air Dried	None	14	0.04	0.13	0.28	0.45	0.62	0.78	3B	7,–20, 21	6
3B1	As in 3A	As in 3B	Paint Added to Siding in 3B	None	6	0.02	0.06	0.11	0.17	0.22	0.27	3B1	20	6
3C	1x4 Boards on 5 in. Centers No. 2 Common	None	5/2–16 in. Red Cedar Shingles—5 in. Exposed	None	69	13.4	39.5	69.5	101.1	135.0	172.0	3C	19, 25	16
3D	As in 3C	Bldg. Paper B.	As in 3C	None	69	0.07	0.22	0.38	0.54	0.70	0.84	3D	19	21
4A	1x6 Air Dried Dressed and End and Side Matched No. 1 Common	Bldg. Paper A Studs Vert.	None	None	29	0.05	0.16	0.31	0.50	0.69	0.90	4A	8,–18	5
4A1	As in 4A	Cut Out	None	None	None	20.0	48.5	80.3	114.1	148.2	184.5	4A1	16	5
4B	1x8 Air Dried Ship-lap No. 2 Common	None	5/2-16 in. Red Cedar Shingles—5 in. Exposed	None	14	2.1	7.5	15.3	24.8	34.9	45.3	4B	9, 10-19	17
4D	None	Bldg. Paper B Studs Vertical	1x6 Air Dried Select Drop Siding Painted	None	4	0.06	0.15	0.23	0.31	0.38	0.45	4D	.....	31
4E	None	As in 4D	As in 4D	1x6 Sheathing End and Side Matched	6	0.06	0.15	0.23	0.31	0.38	0.45	4E	24	32
4F	1x6 Air Dried Dressed End and Side Matched No. 1 Common	None	None	None	None	3.6	13.4	28.3	45.5	63.8	82.7	4F	16, 25	33

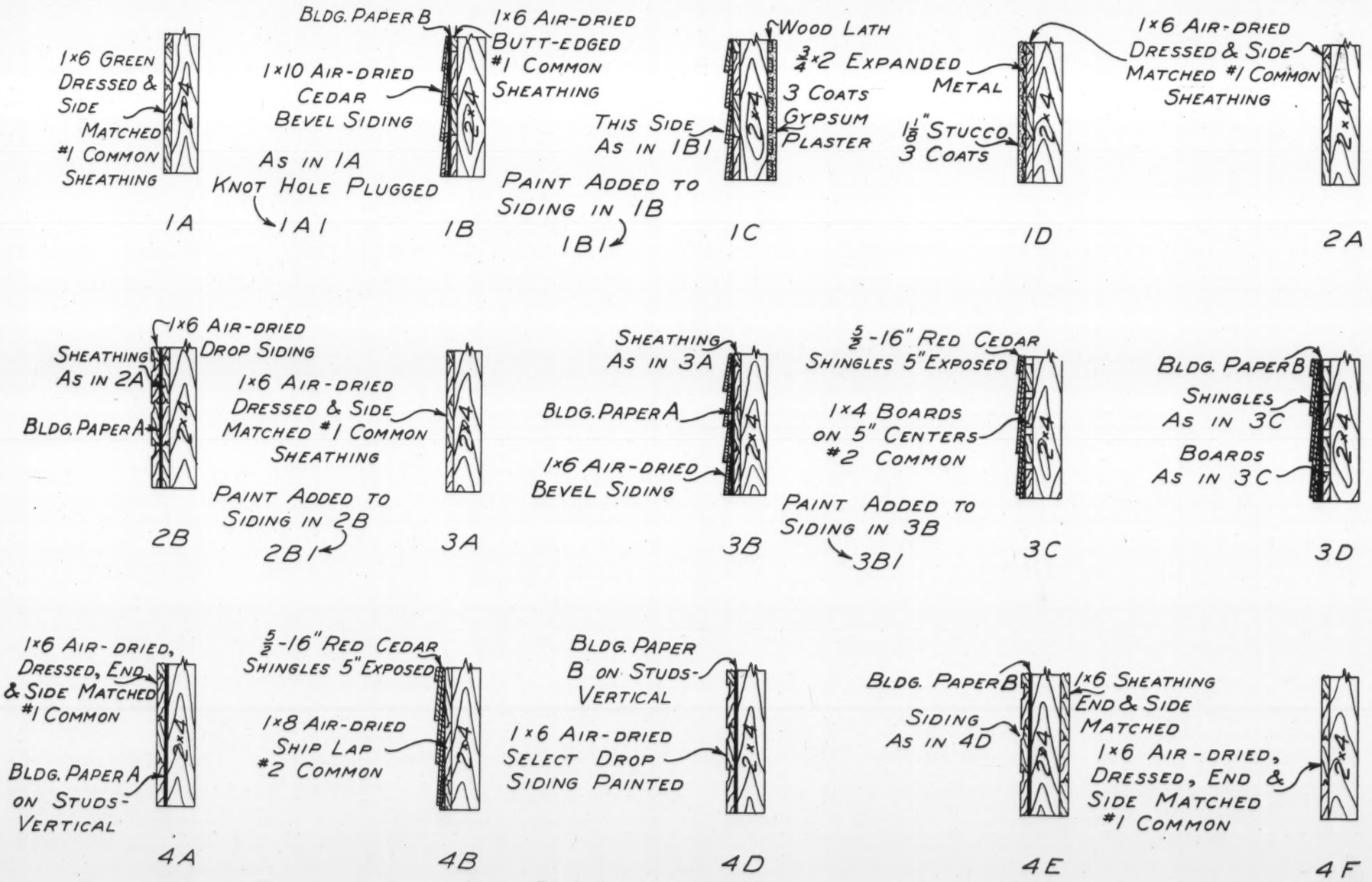


FIG. 2—CROSS-SECTIONS OF PANELS

TABLE 2—DESCRIPTION OF TEST PANELS AND SUMMARY OF RESULTS OF AIR INFILTRATION TESTS

Panel No.	Description of Construction				Standing Period in Days	Air Infiltration in Cu. Ft. Per Hour Per Sq. Ft. of Wall							Index	
	Outside Construction			Inside Construction		Wind Velocity—Miles Per Hr.						Panel No.	To Figures	To Spec
	Sheathing	Bldg. Paper	Siding			5	10	15	20	25	30			
6A	Insulation A Sheathing Board	None	None	None	30	3.8	9.8	16.1	22.5	29.2	36.4	6A	11,-16	7
6B	None	None	Corrugated Steel	None	14	9.0	26.2	45.4	65.1	85.2	106.7	6B	12,-25	9
6C	1x8 Air Dried Ship-lap No. 2 Common	None	24 in. Red Cedar Shingles 11 in. Exposed	None	14	7.2	23.1	43.8	67.1	90.9	116.7	6C	19	19
6D	None	None	1x10 Boards—Spaced 1x4 Battens—Paint	None	14	16.3	49.0	86.9	126.5	165.8	206.0	6D	13,-25	34
7A	Insulation B Sheathing Board	None	None	None	30	1.6	5.0	9.1	13.2	17.8	22.8	7A	16	8
7B	1x6 Boards on 11 in. Centers No. 2 Common	None	24 in. Red Cedar Shingles 11 in. Exposed	None	15	22.1	68.0	122.5	180.4	240.6	307.1	7B	9, 10–19, 25	18
7C	As in 7B	Bldg. Paper B.	As in 7B	None	67	0.02	0.07	0.13	0.19	0.23	0.25	7C	18	20
7D	1x6 Air Dried Ship-lap	Bldg. Paper B.	5/2-16 in. Red Cedar Shingles-7½ in. Exposed	None	7	0.03	0.10	0.17	0.25	0.33	0.42	7D	19, 22	29
7E	As in 7D	As in 7D	As in 7D	Wood Lath and 3 Coats Gyp. Plaster	14	0.02	0.06	0.12	0.18	0.25	0.31	7E	22, 24	30
9A	None	None	None	Wood Lath and 3 Coats Gyp. Plaster	15	0.02	0.08	0.17	0.28	0.40	0.52	9A	14-23	10
9B	None	None	None	As in 9A Plus Decorative Paper	10	0.01	0.05	0.10	0.15	0.20	0.26	9B	23	11
9D	None	None	Insulation A Lath and Stucco	None	29	0.07	0.27	0.39	0.56	0.73	0.90	9D	25	14
9E	1x6 Air Dried End and Side Matched No. 1 Common	None	None	None	2	3.6	13.4	28.3	46.3	64.7	83.8	9E	16, 17, 25	24
9F	As in 9E	PoorGradeResin	None	None	None	0.4	1.5	2.9	4.3	5.3	5.9	9F	17, 18	25
9G	As in 9E	As in 9F	1x6 Drop Siding Painted.	None	13	0.01	0.05	0.10	0.14	0.18	0.21	9G	17	26
10A	None	None	None	Metal Lath and 3 Coats Gyp. Plaster	14	0.03	0.12	0.23	0.35	0.47	0.60	10A	14,-23	12
10B	None	None	None	As in 10A Plus Sizing and Flat Paint	10	0	0	0	0	0	0	10B	23	13
10C	None	None	None	1x6 Sheathing End and Side Matched	7	8.3	26.5	48.8	72.0	96.7	122.8	10C	16, 25	27
10D	None	None	Corrugated Steel	As in 10C	4	1.2	4.0	8.1	12.7	17.4	22.2	10D	24	28
10E	None	None	As in 10D	None	63	1.4	4.7	9.1	13.8	18.5	23.6	10E	25	28

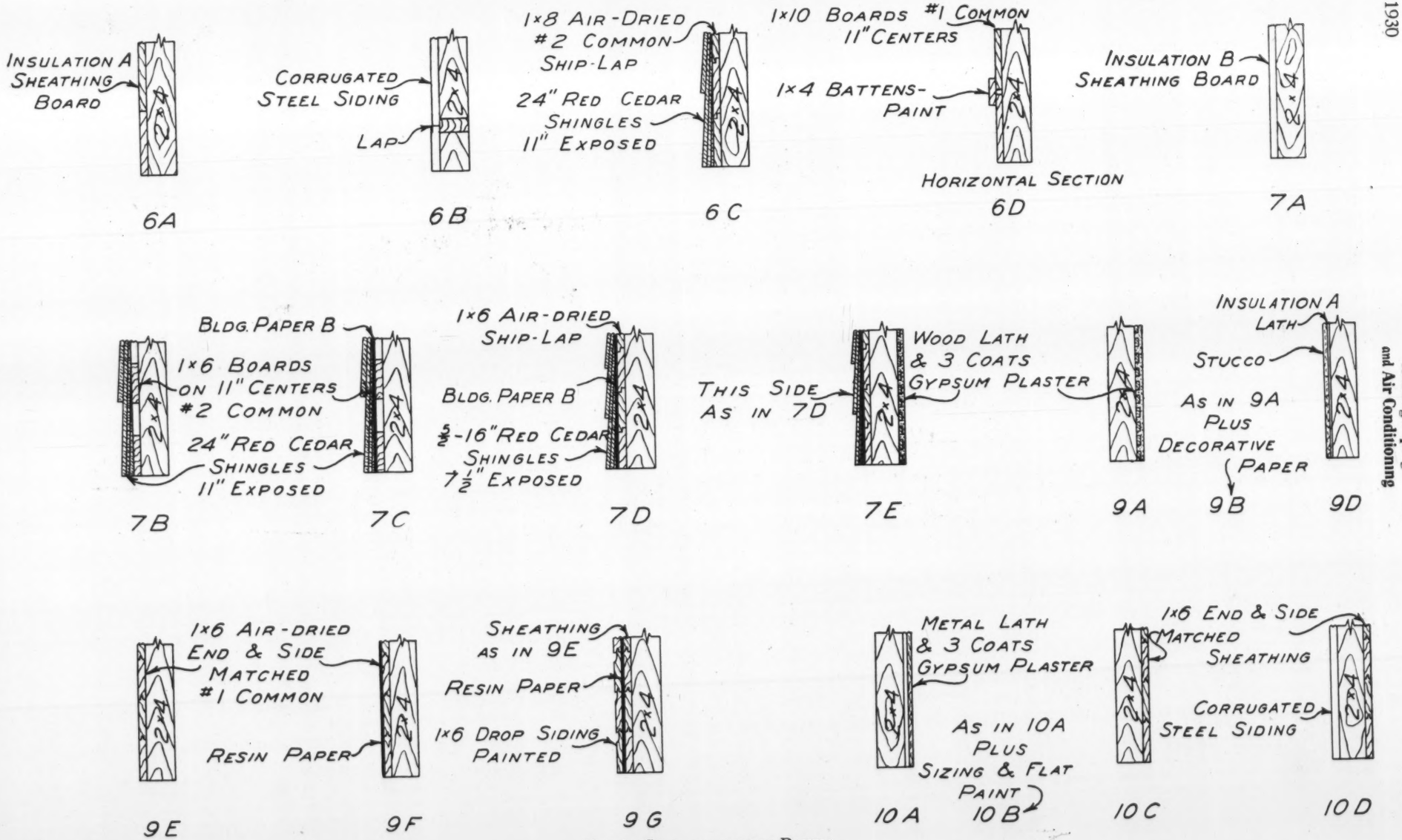


FIG. 3—CROSS-SECTIONS OF PANELS

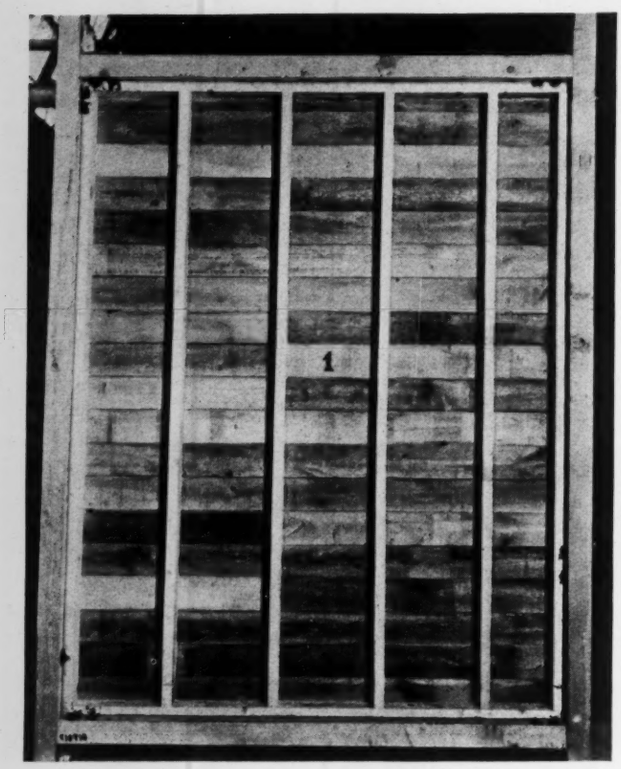


FIG. 4—INTERIOR OF PANEL NO. 1*A*1—GREEN SHEATHING

in place, without disturbing the seal between the test machine chambers and the wall frame, a manhole is provided in each chamber on the side opposite that shown in Fig. 1.

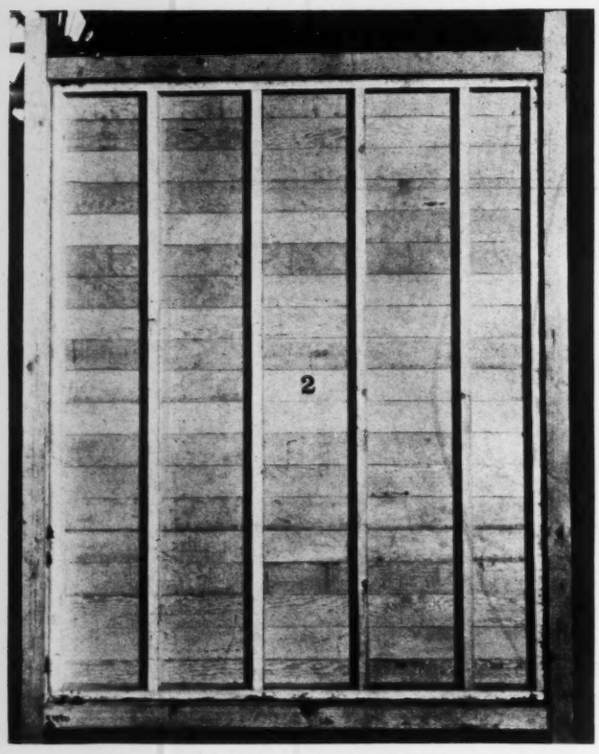


FIG. 5—INTERIOR OF PANEL NO. 2*A*—AIR DRIED SHEATHING

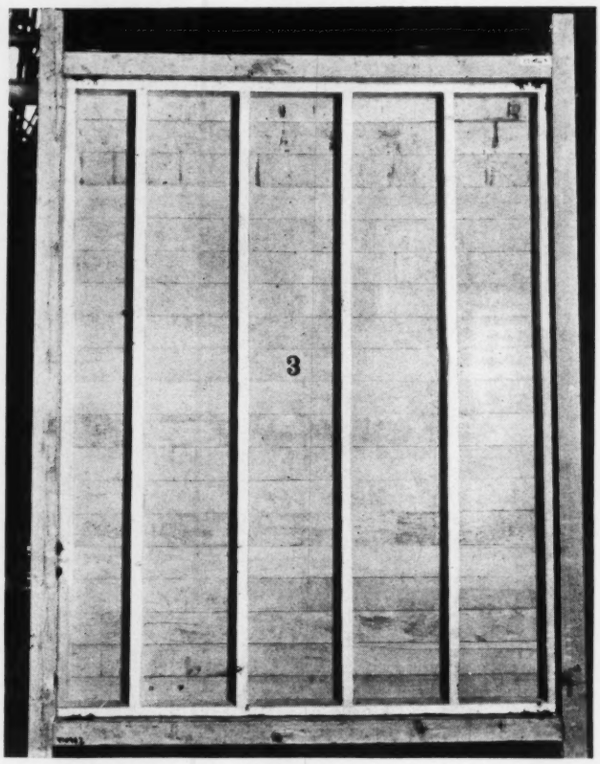


FIG. 6—INTERIOR OF PANEL NO. 3*A*—AIR DRIED SHEATHING

Description of Test Panel Frames

The test panels, described briefly in Tables 1 and 2 and in detail in the appendix of this paper, were built into rectangular frames constructed of four 4x8 air-dried Douglas fir timbers, in the manner shown in Fig. 15.

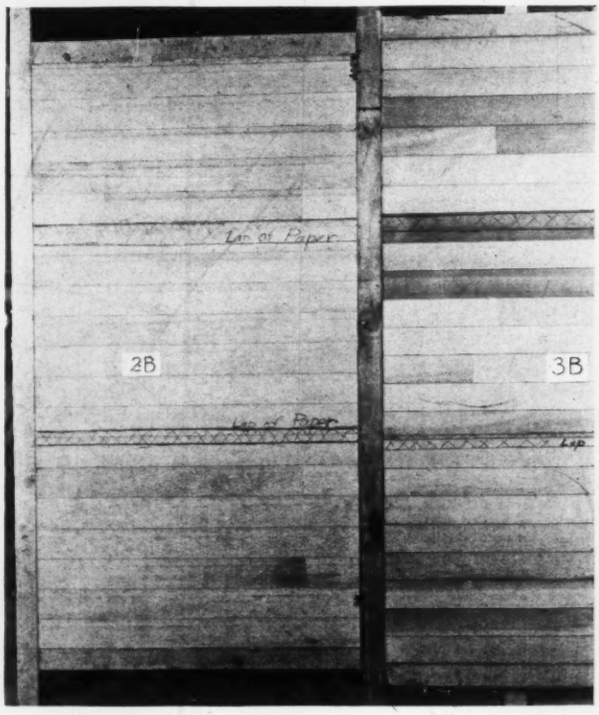


FIG. 7—EXTERIOR OF PANEL NO. 2*B*, SHEATHING, PAPER AND DROP SIDING. EXTERIOR OF PANEL NO. 3*B*, SHEATHING, PAPER AND BEVEL SIDING

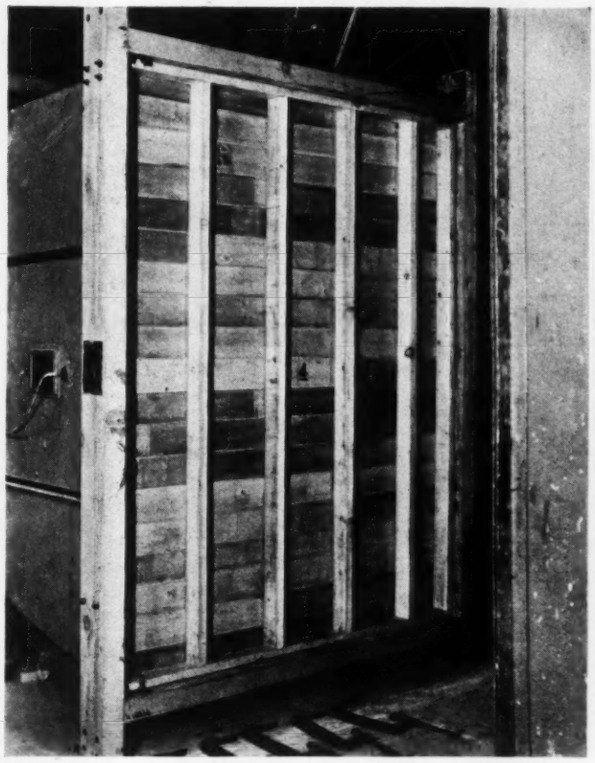


FIG. 8—INTERIOR OF PANEL NO. 4*A*—AIR DRIED SHEATHING

The frame members were secured at the four corners by means of 6 x 6 x ½ in. angle irons, and the joints at these corners were thoroughly sealed with a plastic calking compound.

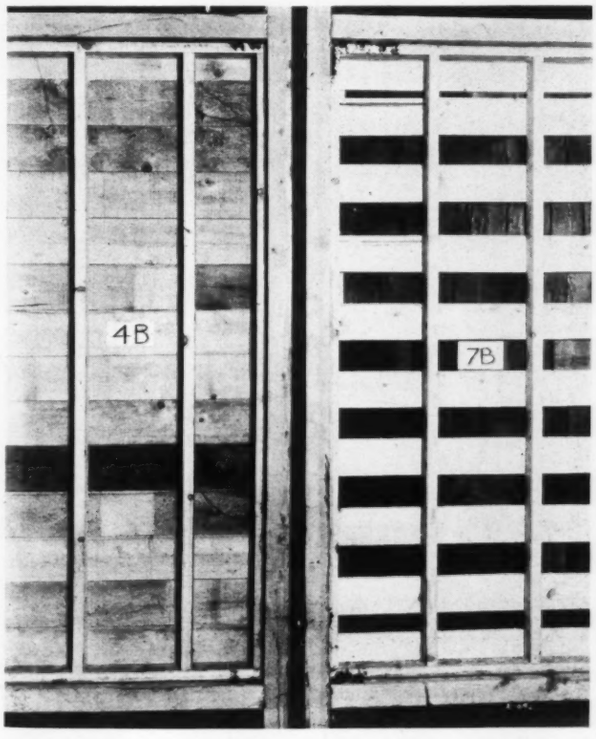


FIG. 9—INTERIOR OF PANEL NO. 4*B*, 16-IN. SHINGLES ON SHIPLAP. INTERIOR OF PANEL NO. 7*B*, 24-IN. SHINGLES ON SPACED BOARDS

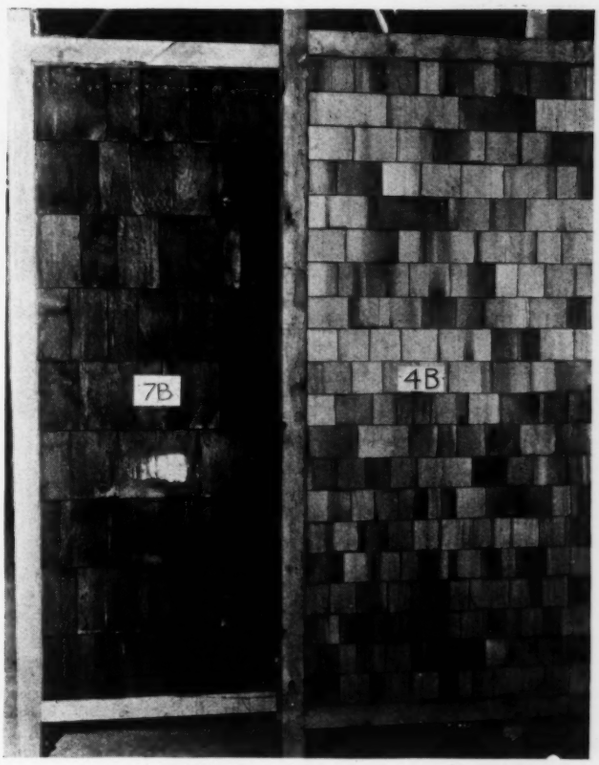


FIG. 10—EXTERIOR OF PANEL NO. 4*B*, 16-IN. SHINGLES ON SHIPLAP. EXTERIOR OF PANEL NO. 7*B*, 24-IN. SHINGLES ON SPACED BOARDS

All construction work was done by a local contractor, under the supervision of L. V. Teesdale of the *U. S. Forest Products Laboratory*, who also passed upon the

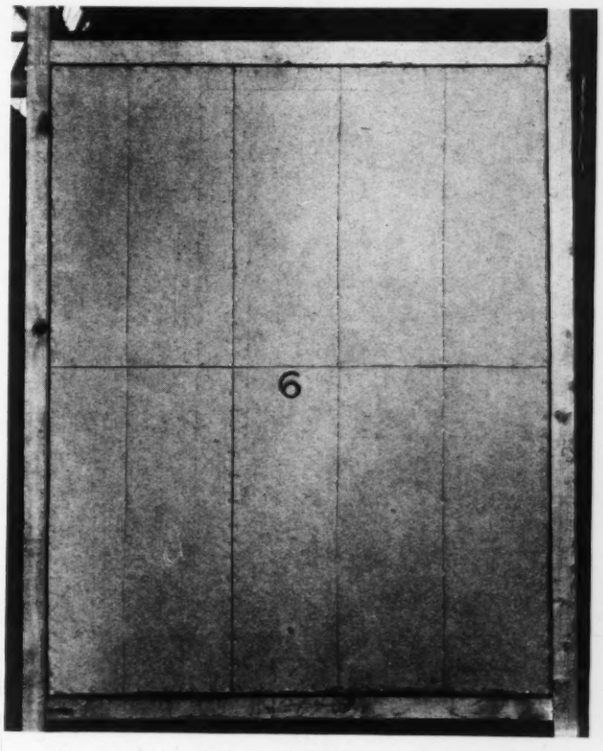


FIG. 11—EXTERIOR OF PANEL NO. 6*A*—FIBRE SHEATHING BOARD

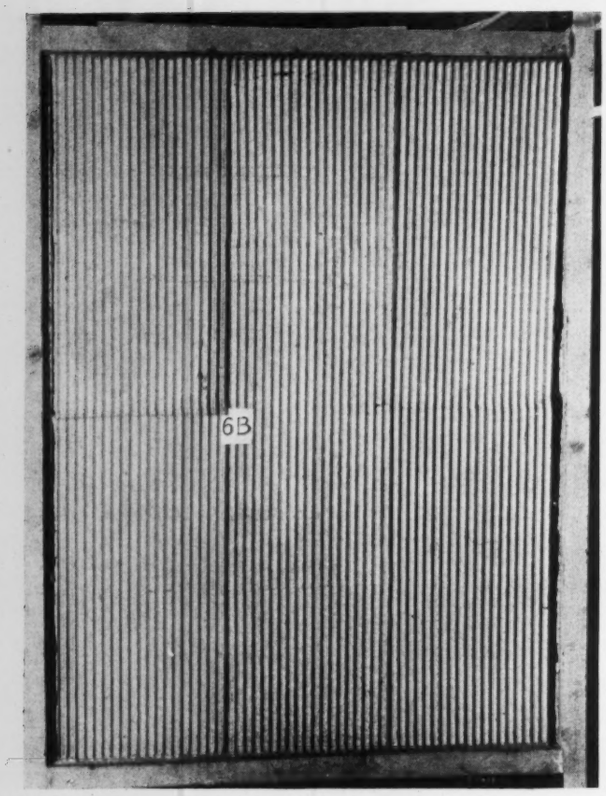


FIG. 12—EXTERIOR OF PANEL NO. 6*B*—CORRUGATED STEEL SIDING

suitability of all construction material, with reference to specifications drawn by the *National Lumber Manufacturers' Association*. Every effort was made to have all construction comparable to that in actual building practice.

Test Procedure

Each test panel was subjected to wind pressure ranging from about 5 to 30 miles per hour, for each of the test conditions as outlined in Tables 1 and 2. Except in the case of Panels *2B* and *3B*, the crack between the frame members and the test panel perimeter was completely sealed with plastic calking compound, leaving only the surface of the panel, 51 sq. ft., open to leakage.

With the exception of the panel described in Item 34 of the appendix, all seasoning periods took place indoors at a temperature of approximately 70 F. The seasoning period for panel *6D*, Item 34, consisted for the most part of sub-zero weather together with one light snowfall and several days of sunshine.

Description of Tables 1 and 2

A brief description of the different constructions built and tested is given in Tables 1 and 2. Cross-sections of the constructions listed in Table 1 are shown in Fig. 2 and for those listed in Table 2 in Fig. 3. More complete descriptions of the constructions built are given in the appendix. The description in the appendix for any particular panel number may be located by referring to the number in the column headed *Index to Specifications*.

Tables 1 and 2, in addition to giving a brief description of the constructions made and tested, list the standing periods from the date of construction to the date of test. Figs. 4 to 15 are photographs of typical wall constructions that were built. The columns headed *Index to Figures* in Tables 1 and 2 list the panel constructions for

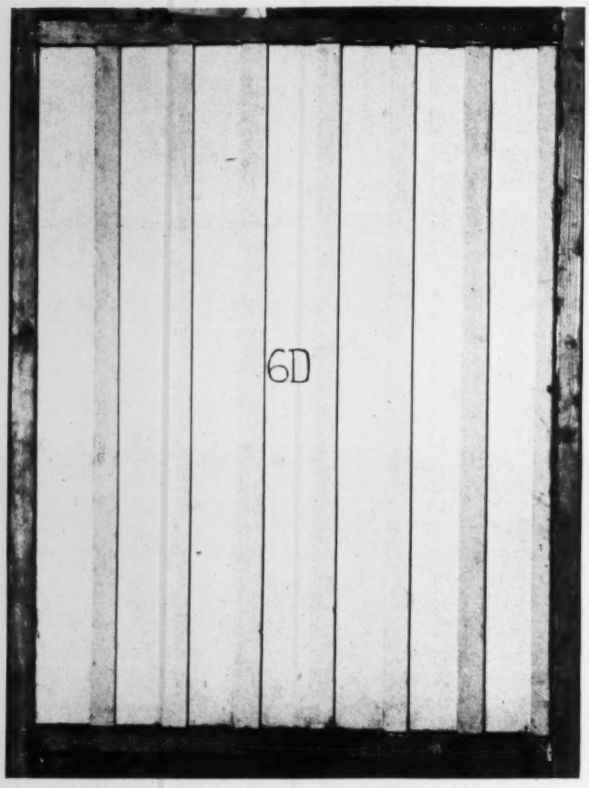


FIG. 13—EXTERIOR OF PANEL NO. 6*D*—1x10 SPACED BOARDS WITH BATTENS

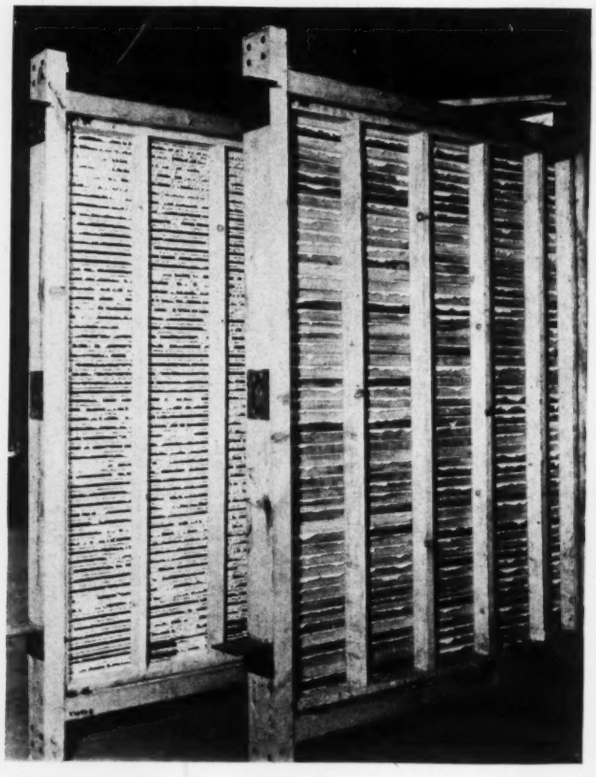


FIG. 14—EXTERIOR OF PANEL NO. 9*A*, PLASTER ON WOOD LATH. EXTERIOR OF PANEL NO. 10*A*, PLASTER ON METAL LATH

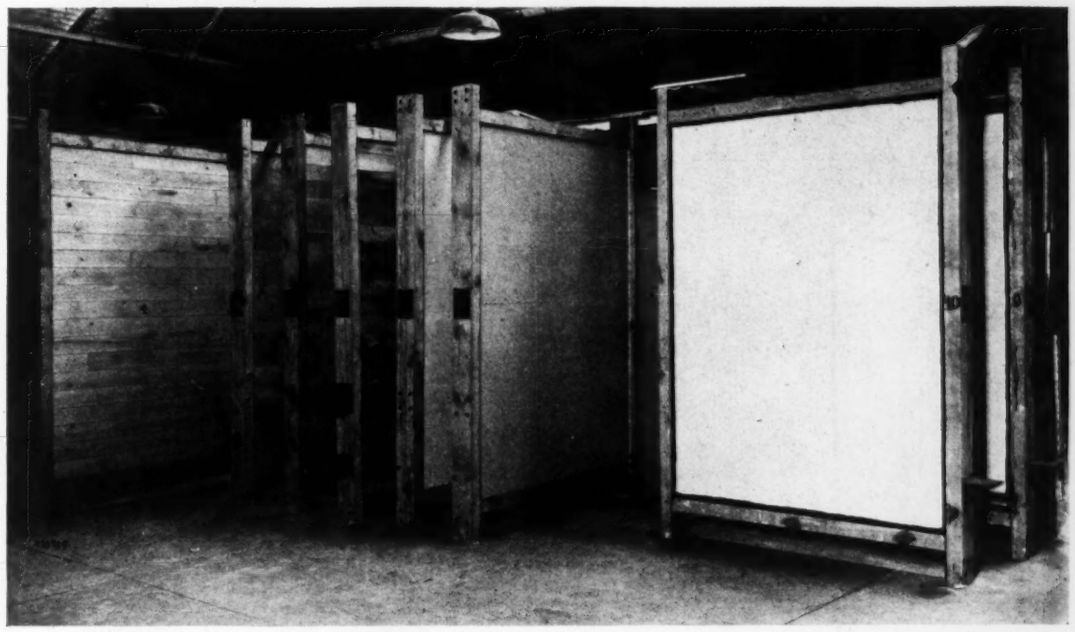


FIG. 15--ASSEMBLY OF TEST PANELS

which photographs are included in this paper. These are the numbers appearing before the dash.

Discussion of Results

The results of the tests on each one of the constructions made are given in Tables 1 and 2 under the heading of *Air Infiltration in Cu. Ft. per Hr. per Sq. Ft. of Wall.* The results are given at wind velocities from 5 to 30 miles per hour by five mile intervals. These wind velocities correspond to drops in pressure in inches of water across the wall as observed during the tests. The relation between the drop in pressure in inches of water and the wind velocity is as follows:

Drop in Pressure in Inches of Water...	0.012	0.048	0.108	0.192	0.300	0.431
Wind Velocity in Miles per Hour...	5	10	15	20	25	30

The test results are shown graphically in Figs. 16 to 25 grouped to show comparisons between various important features. The column headed *Index to Figs.* in Tables 1 and 2 shows the figures in which the test results of each panel number appear. The figure number before the dash is that of the photograph of the wall construction, if any is included, and the numbers after the dash refer to the figures showing the test results graphically. Not all of the test results have been plotted but only those most useful in making comparisons. Tables 1 and 2, however, show the results of all tests and any additional comparisons may be made by referring to the results as tabulated there.

Infiltration Through Sheathing Only

The results of tests on the various sheathings are shown grouped together in Fig. 16. The four tests on air-dried end and side matched sheathing show considerable variation. The average of the four tests shows a

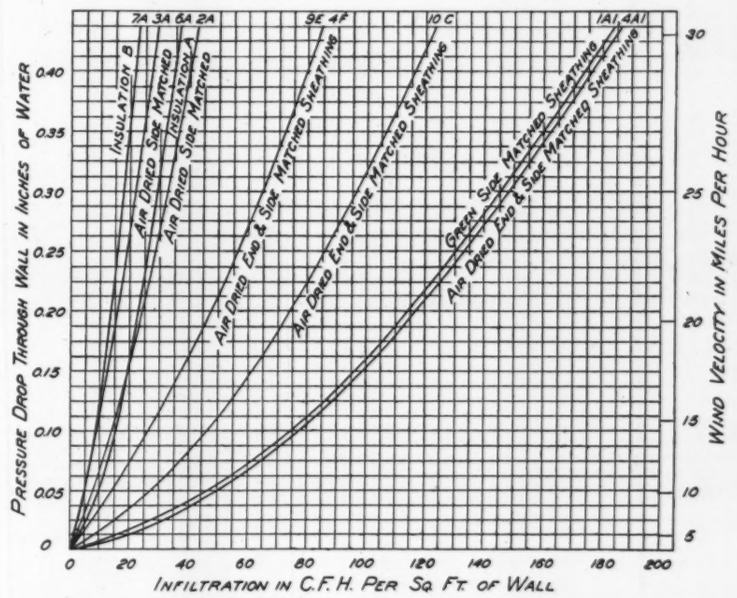

2A 3A 6A 2A
9E 4F
10 C
1A1, 4A1
Insulation B
Air Dried Side Matched
Insulation A
Air Dried Side Matched
Air Dried End & Side Matched Sheathing
Air Dried End & Side Matched Sheathing
Green Side Matched Sheathing
Air Dried End & Side Matched Sheathing
Pressure Drop Through Wall in Inches of Water
0 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
Wind Velocity in Miles Per Hour
5 10 15 20 25 30
0 20 40 60 80 100 120 140 160 180 200
Infiltration in C.F.H. Per Sq. Ft. of Wall

FIG. 16—INFILTRATION THROUGH SHEATHING ONLY

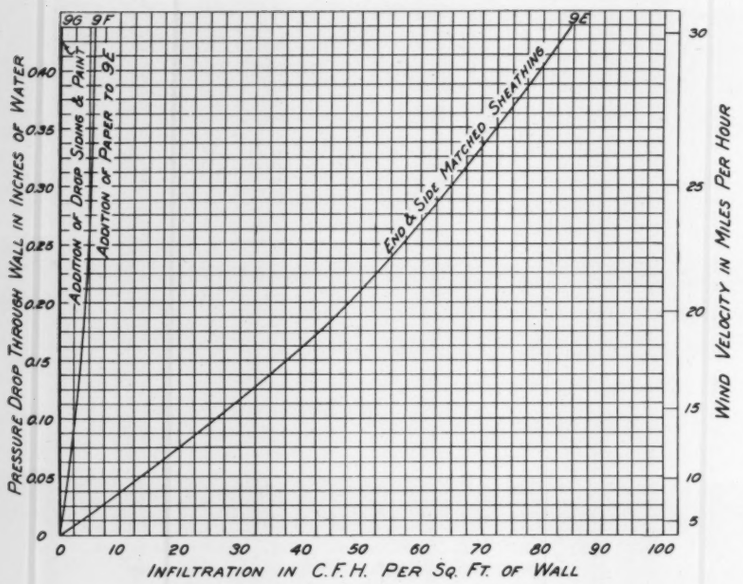

9G 9F
9E
Addition of Drop Siding & Paint
Addition of Paper to 9E
End & Side Matched Sheathing
Pressure Drop Through Wall in Inches of Water
Wind Velocity in Miles Per Hour
Infiltration in C.F.H. Per Sq. Ft. of Wall
0 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
5 10 15 20 25 30
0 10 20 30 40 50 60 70 80 90 100

FIG. 17—ADDITION OF BUILDING PAPER, DROP SIDING AND PAINT TO SHEATHING

leakage of 46.4 cu. ft. per hour per square foot of wall at 15 miles per hour. Of these four end and side matched sheathing panels, 4*F*, 9*E* and 10*C*, were of a uniform material and the average of these would be 35.1 cu. ft. per hour per square foot at 15 miles per hour. As compared to this average, the leakage through Panel 4*A*1 which was of a less uniform material was 80.3 cu. ft. per hour. The lowest leakage secured for end and side matched sheathing was 28.3 cu. ft. per hour per square foot, the value obtained in tests of Panels 4*F* and 9*E*.

The air-dried side matched sheathing on Panel 2*A* showed a leakage of 15.3 cu. ft. per hour per square foot and on Panel 3*A* a leakage of 9.3 cu. ft. per hour per square foot of wall both at 15 miles per hour. This is an average leakage at this wind velocity of 12.3 cu. ft. per hour per square foot. This figure of 12.3 cu. ft. for side matched sheathing is to be compared with the figure of 35.1 cu. ft. for end and side matched sheathing for the same material. In the case of side matched sheathing, all end joints are butted on the studding, whereas many joints with end and side matched sheathing come in between studding. The increase in leakage of end and side matched sheathing over side matched sheathing is considered to be due to greater leakage through the end joints. Figs. 5 and 6 show the air dried side matched sheathing used in Panels 2*A* and 3*A*. The end and side matched sheathing of Panels 4*F*, 9*E* and 10*C* was of this same material.

The leakage through green side matched sheathing, Panel 1*A*1, was 78.6 cu. ft. per hour per square foot at 15 miles per hour. This is slightly less than the leakage through air dried end and side matched sheathing of like material. The comparatively low leakage secured indicates that even with green lumber the shrinkage is not ordinarily enough to pull the tongues and grooves apart and allow the free passage of air. A photograph of Panel 1*A*1 is shown in Fig. 4.

The leakage through fibre board as found in tests of Panels 6*A* and 7*A* was 12.6 cu. ft. per hour per square foot at 15 miles per hour. This is about the same as

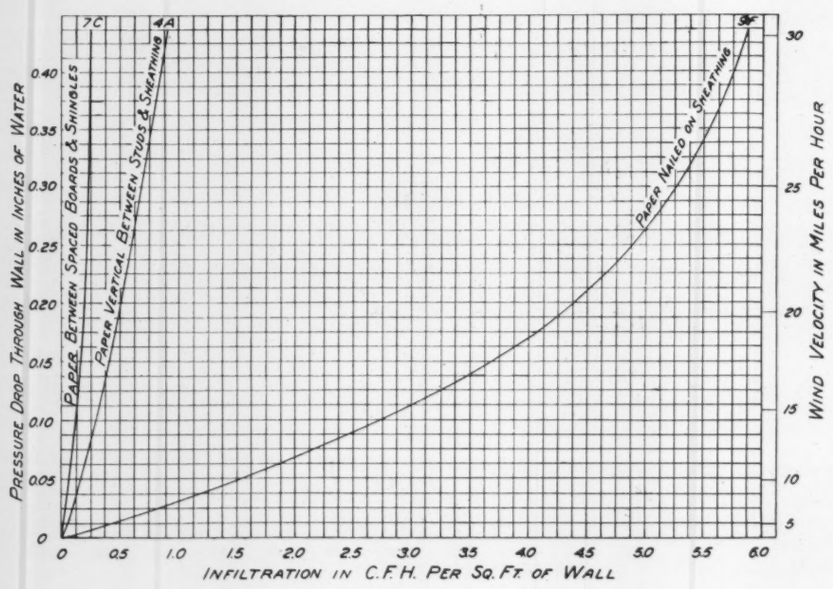

7C
4A
9F
Paper Between Spaced Boards & Shingles
Paper Vertical Between Studs & Sheathing
Paper Nailed on Sheathing
Pressure Drop Through Wall in Inches of Water
Wind Velocity in Miles Per Hour
Infiltration in C.F.H. Per Sq. Ft. of Wall
0 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
5 10 15 20 25 30
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

FIG. 18—STUDY OF VARIOUS APPLICATIONS OF SHEATHING PAPER

through air dried side matched sheathing as determined on Panels 2*A* and 3*A*. The variation in the infiltration found in the two tests of fibre board was due to a variation in the width of the horizontal joints. The sheets were closely fitted together on Panel 7*A*, but a section of the joint on Panel 6*A* had a crack of an appreciable width. Fig. 11 shows a photograph of Panel 6*A*. When the horizontal joints were sealed the leakage for Panels 6*A* and 7*A* was the same. The leakage through a wall of fibre board depends largely on the fit of the horizontal joints and may be considerable with careless workmanship.

Addition of Building Paper, Drop Siding and Paint to Sheathing

Fig. 17 shows the infiltration resulting from tests of the various steps in the building of the outside construction of a wall. The leakage through the sheathing only in Panel 9*E* which was end and side matched was 28.3 cu. ft. per hour per square foot of wall at 15 miles per hour. The application of ordinary resin-sized building paper over the sheathing with the seams nailed at 7 in. intervals reduced the leakage in Panel 9*F* to 2.9 cu. ft. per hour per square foot of wall at 15 miles per hour. The addition of drop siding and paint in Panel 9*G* reduced the leakage to a negligibly small amount. This reduction is due not only to the resistance to air flow of the painted drop siding but also to the increased effectiveness of the sheathing paper because of being clamped between two thicknesses of boards.

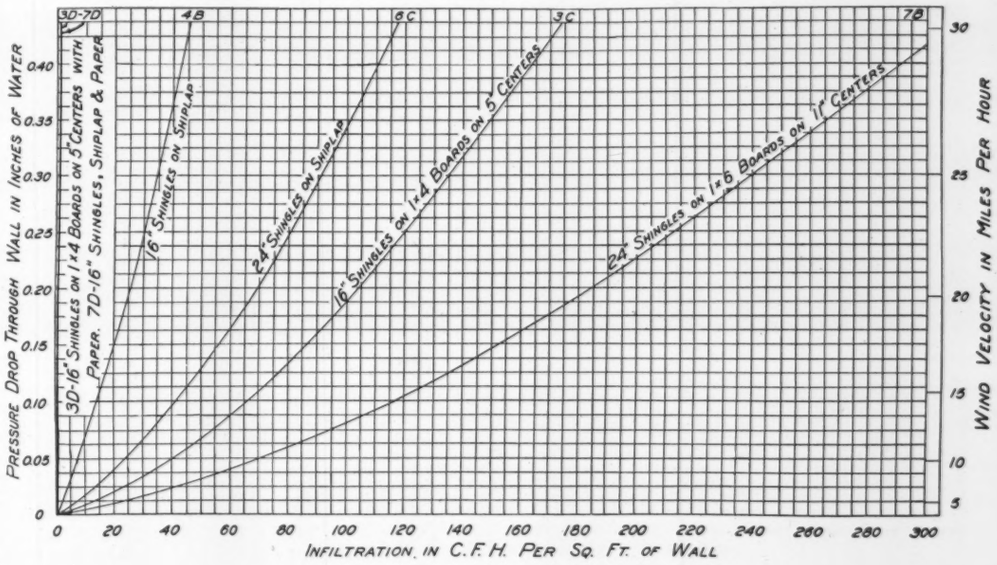

30-7D
4B
6C
3C
7B
30-16" Shingles on 1×4 Boards on 5" Centers with Paper. 7D-16" Shingles, Shiplap & Paper
16" Shingles on Shiplap
24" Shingles on Shiplap
16" Shingles on 1×4 Boards on 5" Centers
24" Shingles on 1×6 Boards on 11" Centers
Pressure Drop Through Wall in Inches of Water
0 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
Wind Velocity in Miles Per Hour
5 10 15 20 25 30
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
Infiltration, in C.F.H. Per Sq. Ft. of Wall

Fig. 19—Infiltration Through Various Types of Shingle Construction

Various Applications of Sheathing Paper

That the effectiveness of sheathing paper depends to a considerable extent on the method of application is shown by the curves in Fig. 18. Paper nailed on the sheathing with the laps nailed at approximately 7 in. intervals in Panel 9*F* showed a leakage of 2.9 cu. ft. per hour per square foot of wall at 15 miles per hour. Paper applied vertically between the studs and sheathing in Panel 4*A* showed a leakage of 0.31 cu. ft. per hour per square foot at 15 miles per hour. In Panel 7*C*, paper was placed between two thicknesses of spaced boards and shingles which by themselves showed an extremely high leakage. The extremely low leakage of 0.13 cu. ft. per hour per square foot at 15 miles per hour found in the test of Panel 7*C* is attributable to the effectiveness of the paper when tightly clamped between two thicknesses.

The paper used on Panel 9*F* was a poor grade of resin paper. In Panel 9*G* drop siding and paint were added which reduced the leakage to a negligibly small amount just as was the case with a good grade of building paper. This is attributable to the reduction in leakage at the laps due to the clamping of the paper between the two thicknesses of sheathing and drop-siding. In the average building construction, a good grade of sheathing paper would probably have a greater resistance to air flow than would a poor paper because of less tearing in application due to its greater tensile strength. Also it probably would maintain its resistance to air leakage better over a period of years against the effects of ageing and weathering.

In the construction of farm and other shelter buildings, the application of paper in the proper way would seem to be worth while. There are two ways of applying the paper between the studding and the sheathing, horizontally and vertically. Horizontal application between studding and sheathing would correspond in leakage to the results secured in test of Panel 9*F* where the sheathing paper was applied horizontally on the outside of the sheathing and nailed at intervals. Vertical application between studding and sheathing was made in Panel 4*A* and showed considerably less leakage than horizontal application.

Air Infiltration Through Various Types of Shingle Construction

Fig. 19 shows the results of tests on various shingle constructions. The greatest leakage was secured with 24-in. shingles nailed to 1 x 6 boards spaced on 11-in. centers in Panel 7*B*. This leakage was 122.5 cu. ft. per hour per square foot of wall at 15 miles per hour. The corresponding construction for 16-in. shingles and 1 x 4 boards on 5-in. centers in Panel 3*C* showed a leakage of 69.5 cu. ft. per hour per square foot. In both of these

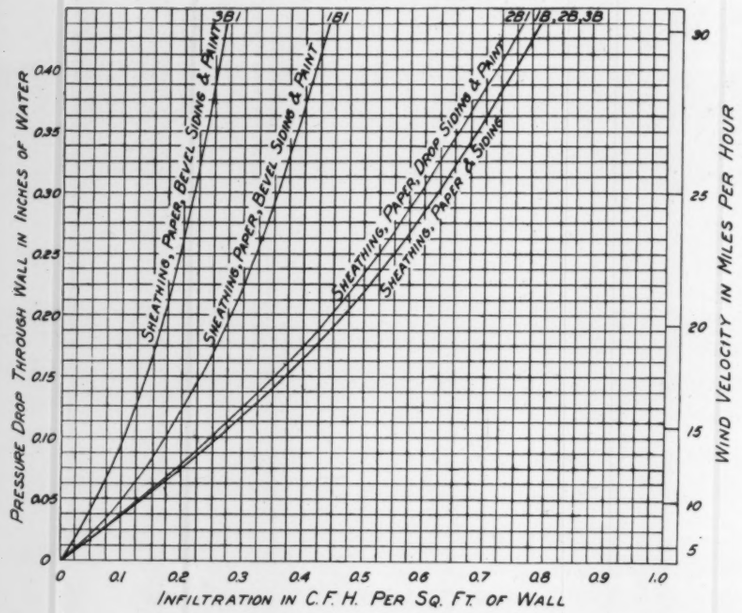

3B1
1B1
2B1 1B, 2B, 3B
SHEATHING, PAPER, BEVEL SIDING & PAINT
SHEATHING, PAPER, BEVEL SIDING & PAINT
SHEATHING, PAPER, DROP SIDING & PAINT
SHEATHING, PAPER & SIDING
PRESSURE DROP THROUGH WALL IN INCHES OF WATER
0 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
WIND VELOCITY IN MILES PER HOUR
5 10 15 20 25 30
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
INFILTRATION IN C.F.H. PER SQ. FT. OF WALL

FIG. 20—ADDITION OF PAINT TO DROP SIDING AND BEVEL SIDING

constructions, the spaced boards act merely as pieces to nail the shingles to and play practically no part in the stopping of air leakage.

The replacing of the spaced boards with shiplap in the case of 24-in. shingles in Panel 6*C* reduced the leakage to 43.8 cu. ft. per hour per square foot at 15 miles per hour. The corresponding value for 16-in. shingle construction in Panel 4*B* was 15.3 cu. ft. per hour per square foot. The use of shiplap in shingle roof and side wall construction would seem to be advisable in the reduction in infiltration.

The application of sheathing paper to a 16-in. shingle construction using spaced boards in Panel 3*D* and to a 16-in. shingle construction using shiplap in Panel 7*D* reduced the air infiltration to the negligibly small amount of less than one-half cubic foot per hour per square foot of wall. The great reduction secured by the use of paper in a shingle wall would make its use advisable in any construction where infiltration is objectionable. One construction where the use of paper would be highly desirable is in shingle roof construction on residences.

Addition of Paint to Siding

The infiltration of air through a wall having building paper properly applied is negligibly small. This amount was 0.28 cu. ft. per hour per square foot of wall at 15 miles per hour for Panels 1*B*, 2*B* and 3*B*. Fig. 20 shows the results of these tests plotted to a very much enlarged scale. The application of paint to the siding on these panels resulted in a further reduction.

In the case of Panel 2*B*1, having drop siding, the reduction was very slight, but was an appreciable amount in Panels 1*B*1 and 3*B*1 having bevel siding. This indicates that paint seals the joints in bevel siding better than in drop siding. This reduction in either case is extremely small since the sheathing paper clamped between the sheathing and siding by itself is very effective in preventing air infiltration. This reduction in leakage

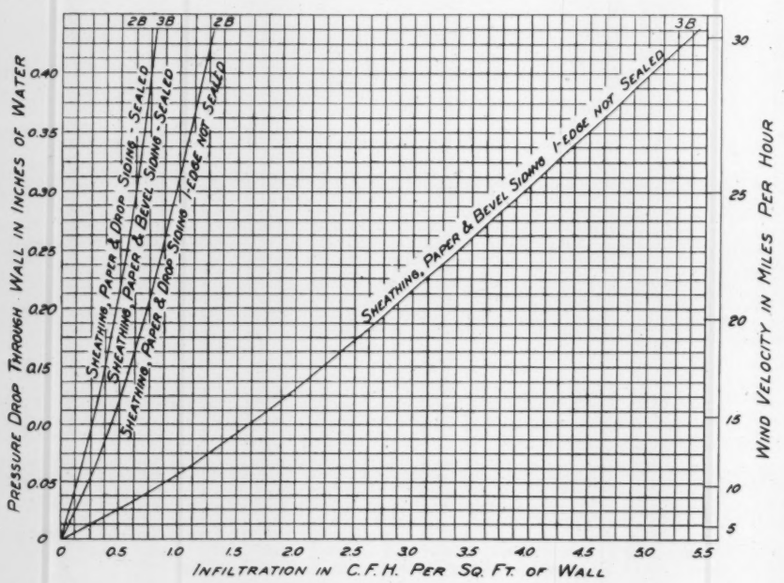

2B 3B
2B
3B
SHEATHING, PAPER & DROP SIDING - SEALED
SHEATHING, PAPER & BEVEL SIDING - SEALED
SHEATHING, PAPER & DROP SIDING 1-EDGE NOT SEALED
SHEATHING, PAPER & BEVEL SIDING 1-EDGE NOT SEALED
PRESSURE DROP THROUGH WALL IN INCHES OF WATER
0 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
WIND VELOCITY IN MILES PER HOUR
5 10 15 20 25 30
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5
INFILTRATION IN C.F.H. PER SQ. FT. OF WALL

FIG. 21—STUDY OF GOOD AND POOR CONSTRUCTIONS

due to the addition of paint probably is not permanent since it would take very little movement due to weathering or to changes in humidity to break the paint film sufficiently to allow air to reach the sheathing paper quite freely as compared to its passage through the paper layer. Paint applied to a weathered siding would of course reduce the size of the cracks at joints in the siding.

A Study of Good and Poor Corner Constructions

In the case of Panels *2B* and *3B* tests were first made with the joint between the wall and the frame calked on only three sides. On the fourth side, the joint at the depth of the sheathing only was calked. This allowed air to get under the siding and under the paper from this uncalked end joint. This is considered to be approximately the condition at the corner of a frame building or against window or door openings with poor construction. Here there is a chance for air to get under the trim, then to get under the siding and seek out openings in the layer of paper. Unless the paper is very carefully applied, there would also be the chance for air to find its way under it directly at the corner or at the window or door frame.

Fig. 21 shows the results of these tests with one edge of the siding and paper not sealed. The results on Panel *3B* showed a leakage of 1.70 cu. ft. per hour per square foot of wall at 15 miles per hour for a wall equipped with bevel siding. The corresponding results on Panel *2B* equipped with drop siding was 0.45 cu. ft. This indicates that drop siding, since it presses down over the entire paper surface quite effectively, prevents air from getting under the paper from an end joint such as occurs at the corner of a building or at window or door frames. The bevel siding, since it makes only line contact with the paper, is not so effective in preventing air from getting under the paper. This points to the need for carefully wrapping the paper around the corner of a building and for the making of a tight seal in the paper layer at window and door openings. In the case of bevel siding with the best paper application at such locations, there is still the chance for air to travel horizontally in the air spaces under the siding and seek out defects in the paper. This calls for careful application not only at corners and openings but over the entire wall surface. It is also important that laps in the paper layer come under lines of contact when bevel siding is to be applied.

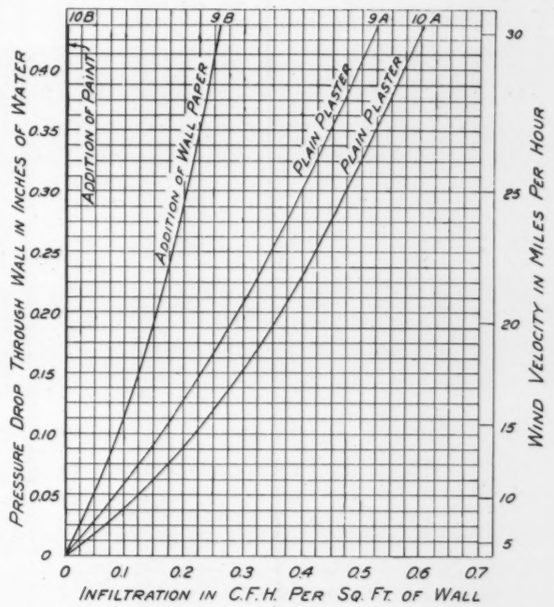

10B
9B
9A
10A
ADDITION OF PAINT
ADDITION OF WALL PAPER
PLAIN PLASTER
PLAIN PLASTER
PRESSURE DROP THROUGH WALL IN INCHES OF WATER
0 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
WIND VELOCITY IN MILES PER HOUR
5 10 15 20 25 30
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
INFILTRATION IN C.F.H. PER SQ. FT. OF WALL

FIG. 23—ADDITION OF WALL PAPER AND PAINT TO PLASTER

When the fourth side of Panels *2B* and *3B* was sealed, the leakage was reduced to the negligibly small amount of 0.28 cu. ft. per hour per square foot. Fig. 7 shows a photograph of these two panels.

Addition of Plaster to Walls Having Sheathing Paper

The results of tests on Panel *1B1* made of sheathing, paper and bevel siding and Panel *7D* consisting of shiplap, paper and shingles are plotted in Fig. 22 to a greatly exaggerated scale. The leakages for these two constructions were 0.18 and 0.17 cu. ft. per hour per square foot

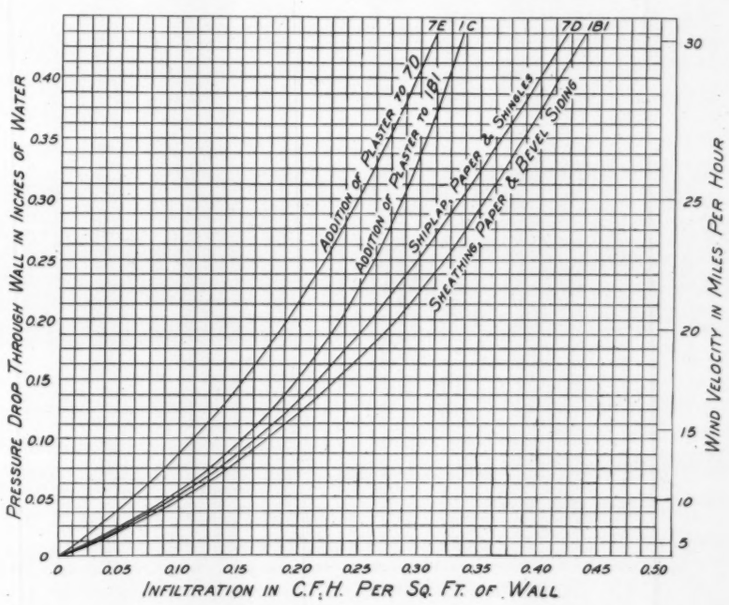

7E
1C
7D
1B1
ADDITION OF PLASTER TO 7D
ADDITION OF PLASTER TO 1B1
SHIPLAP, PAPER & SHINGLES
SHEATHING, PAPER & BEVEL SIDING
PRESSURE DROP THROUGH WALL IN INCHES OF WATER
0 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
WIND VELOCITY IN MILES PER HOUR
5 10 15 20 25 30
0 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
INFILTRATION IN C.F.H. PER SQ. FT. OF WALL

FIG. 22—ADDITION OF PLASTER TO WALLS HAVING SHEATHING PAPER

at 15 miles per hour. These are extremely small leakages. The addition of plaster to these two constructions in Panels 1*C* and 7*E* resulted in a further reduction of this negligibly low leakage.

Tests on plaster constructions alone in Panels 9*A* and 10*A* showed the negligible leakage of 0.17 and 0.23 cu. ft. per hour per square foot at 15 miles per hour.

Having practically air tight layers such as building paper and plaster at two points in a wall should reduce air movements within the wall and thereby exert a beneficial effect on heat losses by transmission.

Addition of Wall Paper and Paint to Plaster

Plaster by itself allows only a negligible amount of air leakage. The results of tests of plastered Panels 9*A* and 10*A* are plotted to an exaggerated scale in Fig. 23. The infiltration averaged 0.20 cu. ft. per hour per square foot at 15 miles per hour. The tests were made with no cracks in the plaster and the panels were sealed completely on all four sides. Had cracks been present or had imperfect sealing been made at an edge of the plaster sheet corresponding to poor sealing at the baseboard or at a window opening in actual construction, the leakage would have been much greater. To obtain the effectiveness of plaster against air leakage good workmanship includes the proper sealing of the plaster sheet at the baseboard and window trim.

The addition of wall paper in Panel 9*B* to the plaster in Panel 9*A* resulted in a considerable although unimportant reduction in air leakage. The addition of sizing and flat wall paint in Panel 10*B* to the plaster in Panel 10*A* made the wall practically air tight. The leakages of the plain plaster walls were negligibly small. The application of paint or paper under such circumstances would have to be justified by other reasons than a reduction in air infiltration. Probably the application of paint or paper to a badly cracked plaster wall would have a favorable effect on air leakage.

Infiltration Through Various Types of Compound Walls

A compound wall for the purposes of this paper is defined as one that has a finished construction on both sides of the studding. The results of tests on the four compound walls that were built are shown in Fig. 24. The three panels 1*C*, 4*E* and 7*E* all had in their construction sheathing paper and plaster, although different types of siding were used. The leakages secured were 0.16, 0.23 and 0.12 cu. ft. per hour per square foot at 15 miles an hour or an average for the three walls of 0.17 cu. ft.

Panel 10*D* contained neither sheathing paper nor plaster and had corrugated steel siding as the outside construction and end and side matched sheathing as the inside construction. The leakage at 15 miles an hour was 8.1 cu. ft. per hour per square foot. Had paper been applied vertically between the studding and the boards as in Panel 4*A*, the leakage would have been less than one cubic foot per hour per square foot of wall.

Infiltration Through Single-Surfaced Walls Used in Farm and Other Shelter Buildings

Fig. 25 shows the results of tests on panels having a single thickness. These include panels having tongued and grooved boards both butt ended and end matched, boards and battens and corrugated steel siding.

The largest leakage occurred with Panel 6*D* which was built of 1 x 10 in. boards spaced on 11 in. centers and the spaces covered with 1 x 4 in. boards. This leakage was 86.9 cu. ft. per hour per square foot of wall at 15 miles per hour. Fig. 13 is a photograph of this panel.

The leakage through the three panels 4*F*, 9*E* and 10*C* of air dried end and side matched sheathing of a uniform material averaged 35.1 cu. ft. per hour per square foot of wall at 15 miles per hour. The inclusion of the fourth panel of a different material, Panel 4*A*1, of end and side matched sheathing increased the average to 46.4 cu. ft. per hour per square foot of wall at 15 miles per hour. Air dried side matched sheathing in Panels 2*A* and 3*A* showed an average leakage of 12.3 cu ft. per hour per square foot at 15 miles per hour.

Two panels, 6*B* and 10*E*, were tested having corrugated steel siding. The leakage through Panel 6*B* was 45.4 cu. ft. and through Panel 10*E*, 9.1 cu. ft. per hour per square foot at 15 miles per hour. The average of the two is 27.3 cu. ft. per hour per square foot. The

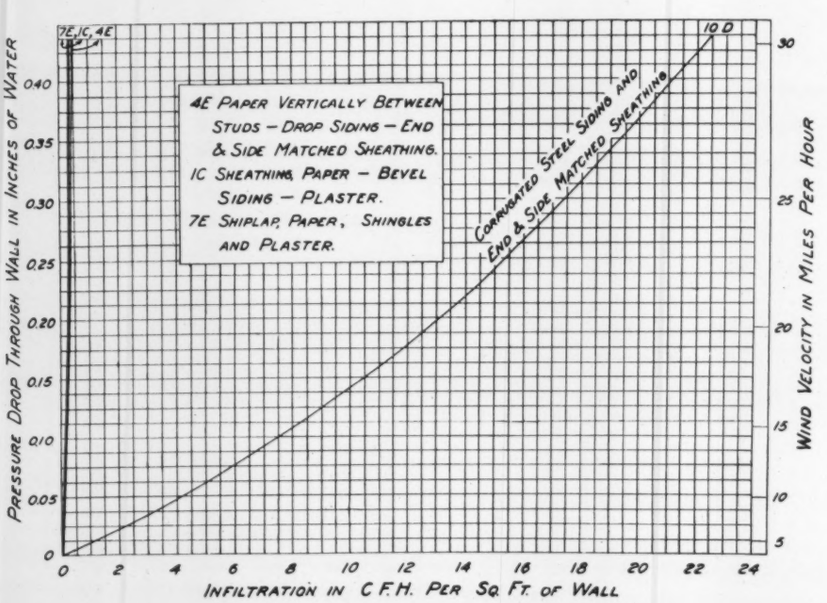

7E, 1C, 4E
10 D
4E PAPER VERTICALLY BETWEEN STUDS – DROP SIDING – END & SIDE MATCHED SHEATHING.
1C SHEATHING PAPER – BEVEL SIDING – PLASTER.
7E SHIPLAP, PAPER, SHINGLES AND PLASTER.
CORRUGATED STEEL SIDING AND END & SIDE MATCHED SHEATHING
PRESSURE DROP THROUGH WALL IN INCHES OF WATER
0 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
WIND VELOCITY IN MILES PER HOUR
5 10 15 20 25 30
0 2 4 6 8 10 12 14 16 18 20 22 24
INFILTRATION IN C.F.M. PER SQ. FT. OF WALL

FIG. 24 — INFILTRATION THROUGH VARIOUS TYPES OF COMPOUND WALLS

large variation in results is explainable in a difference in the length and fit of the horizontal joints. Panel 6*B* had 1-1/3 horizontal joints and Panel 10*E* had only one horizontal joint. The fit of some of the horizontal joints on Panel 6*B* was poorer than that on Panel 10*E*.

Fig. 12 shows a photograph of Panel 6*B*. The joint between the steel siding and the test frame was calked on all four sides during the tests. Had air been allowed to enter the ends of the corrugations at the top or bottom of the wall, the leakage would have been exceedingly large. Such would be the condition in actual building construction unless special care were taken in the application to butt the sheets against wood construction.

The tests on all of the single-surfaced walls show considerable leakage. The application of sheathing paper nailed vertically on the studding to any single-surfaced wall would greatly reduce the leakage. The leakage of such an application was shown in the test of Panel 4*A* to be less than one cubic foot per hour per square foot of wall at 15 miles per hour.

Conclusions

The air infiltration through a frame wall construction containing building paper or plaster properly applied is negligibly small.

The best application of building paper consists of the clamping of the paper between two thicknesses such as sheathing and drop siding or shingles. In a single-surfaced wall, the paper may be effectively applied vertically on the studding under the boards. Special precautions are necessary at the corner of a building or against door or window openings to make the paper effective.

While no difference has been found in the value of a high and a low grade paper on these infiltration tests, likely the good grade of paper will better maintain its efficiency against air infiltration over a period of years than will the poor grade of paper. A paper having considerable weight and strength should develop fewer defects in application than would a poor paper. The use of a poor grade of paper is particularly objectionable for a construction in which the paper is not firmly clamped between two thicknesses of material over its entire surface.

End and side matched sheathing has a somewhat greater leakage to air than has side matched sheathing. The difference is of no importance when sheathing paper is included in the construction. End and side matched sheathing presents the same desirable flat surface for application of paper as does side matched sheathing. There is no disadvantage from the infiltration standpoint to offset the advantages of the use of end and side matched sheathing on the usual building construction. With end and side matched sheathing, random lengths may be used, resulting in a saving in material and sawing labor.

The application of building paper to single-surfaced frame walls such as are used for farm and other shelter buildings can be effectively and cheaply performed. The application of the paper vertically between the studding and the sheathing and with the laps on the studding makes a very good construction from the infiltration standpoint.

To obtain the full efficiency of a frame wall against air leakage, special care must be used at the corners of a building and against window and door openings. Building paper should be carefully wrapped around the corner so as to prevent air getting through the wall construction at this point.

In the case of bevel siding, there is the chance for air to enter at a corner construction and travel horizontally to seek out defects in the sheathing paper. This requires the careful application of the paper so as to prevent defects developing and the use of wide laps so as to bring them under the contact lines of the bevel siding. The use of a good grade of paper would be economical due to freedom from tearing during application and the maintaining of a high degree of effectiveness throughout the life of the building.

Drop siding does not present spaces for air travel over the surface of the sheathing paper and very effectively holds the paper against the sheathing. Poor corner construction is a less serious factor with drop siding than with bevel siding.

The use of building paper is justified from an infiltration standpoint in any shingle roof or side wall construction. The use of shiplap rather than spaced boards is desirable in the clamping of the sheathing

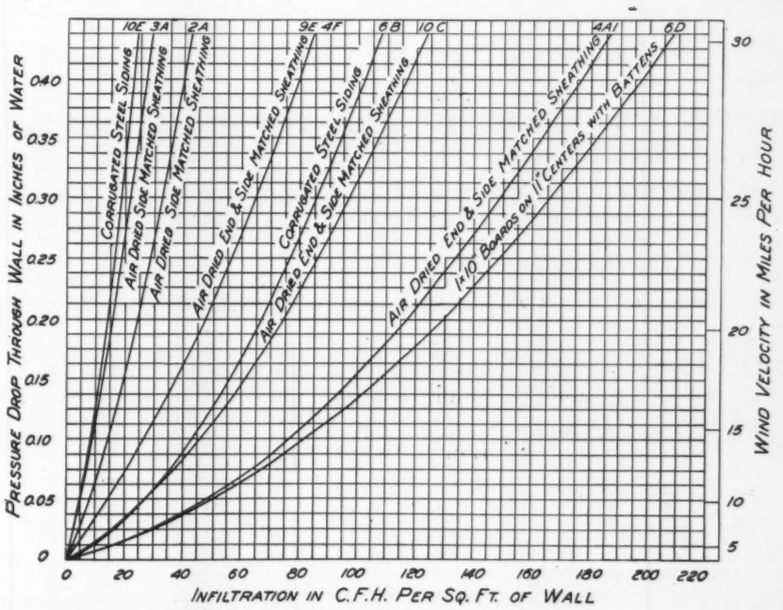


Fig. 25—Infiltration Through Single Surface Walls Used in Farm and Other Shelter Buildings

paper securely over its entire surface. This minimizes the buckling of the paper from ageing. In districts where heating seasons are mild, the inclusion of building paper and the use of shiplap rather than spaced boards would be justified by the reduction in infiltration.

Plaster by itself allows the passage of only a negligible amount of air when properly applied. Proper application means the sealing at the baseboard and against window and door openings by running the plaster tightly against the floor or frame construction of an opening. The full effectiveness of plaster is probably seldom obtained. The development of cracks reduces the efficiency of the plaster. The application of paint or wall paper is not justified from the standpoint of infiltration reduction on a plaster wall that is fully effective, but on a cracked plaster surface the application of either paint or paper may reduce infiltration considerably.

The effectiveness of plaster properly applied is no justification for the use of low grade building paper or of the poor construction of the wall containing it. Not only is it difficult to secure and maintain the full effectiveness of the plaster but also it is highly desirable to have two points of high resistance to air flow with an air space between them to keep heat transmission losses at a minimum.

APPENDIX

Description of Test Panels

Items 1 and 2. Eight test panel frames were built of 4 x 8 timbers as described in the forepart of the paper. To the top and bottom members of each of these frames single 2 x 4 plates were nailed 1½ in. from the face of the frame and extending from end to end of the frame opening. Vertical 2x4 studs were installed between these plates on 16-in. centers, except that the end studs were spaced such as to bring end studs tightly against the vertical frame members. Studs were firmly toe nailed to plates and end studs to frame. A recess was made against the frame members in the 2x4 plates and end studs on both sides of the frame into which calking compound was packed to prevent air leakage at this joint.

Item 3. Over the stud frame in panel frame No. 1, 1x6-in. dressed and side matched sheathing was applied with ends butted over studs, fitted with ordinary care to secure tightness and face nailed twice at each stud with 8*d* nails. Joints were broken over studs in every third course. This material was green and of No. 1 Common grade. Green sheathing, in this test, consisted of air-dried sheathing that had been soaked in water for several days. The panel was allowed to season 29 days before testing.

Item 4. Over the studding in panel frames Nos. 2 and 3, 1x6-in. dressed and side matched sheathing was applied. Workmanship was in all respects similar to that of *Item 3*, except that the sheathing was thoroughly air-dried when applied. These panels were allowed to season 28 days before testing.

Item 5. Over the stud frame in panel frame No. 4, a good grade of sheathing paper termed, Building Paper *A*, was applied in vertical strips, lapped 2 in. over studs and tacked to studs with roofing nails. Over the building paper, 1x6-in. dressed, and end and side matched No. 1 Common sheathing was applied. Workmanship was similar in all respects to that required for *Item 3*, except that no effort was made to have the end joints between boards occur over studs. End joints were made in not less than two-thirds of the courses, but each board spanned at least two studs. The panel was allowed to season 29 days before testing. Immediately after testing the paper and siding, the paper was cut out between studs with a knife and the panel re-tested.

Item 6. Over the sheathing on panel frames Nos. 2 and 3 after test, Building Paper *A* was applied in horizontal strips lapped not less than 2 in. and with one vertical joint one strip wide, also lapped, in the center of the panel.

Over the building paper on panel No. 2, 1x6-in. drop siding was applied. This siding was air dry to the satisfaction of the Inspector, and was nailed in accordance with usual practice. The panel was allowed to season 14 days and then tested. Three coats of good commercial white lead and zinc paint were then applied to the siding at customary intervals, and 6 days after the application of the final coat, the panel was re-tested.

Over the building paper on panel frame No. 3, 1x6-in. bevel siding was applied lapped not less than 1 in. and nailed in accordance with usual practice. The panel was allowed to season 14 days and then tested. Three coats of good commercial white lead and zinc paint were then applied to the siding at customary intervals, and 6 days after the application of the final coat the panel was re-tested.

Item 7. Over the stud frame in panel frame No. 6, Insulation *A* sheathing board was applied, using one vertical joint butted over studding and one horizontal joint clear across panel. The panel was allowed to season 30 days before testing.

Item 8. Over the stud frame in panel frame No. 7, Insulation *B* standard sheathing board was applied in a manner similar to the Insulation *A* (see *Item 7*) nailed according to manufacturer's specifications. The panel was allowed to season 30 days before testing.

Item 9. Insulation *A* sheathing board was removed from studding in panel frame No. 6 and 20-gage galvanized corrugated sheet steel siding applied. Sheets were about 27 in. wide and 60 in. long and were lapped and nailed on to the studding according to manufacturer's specifications for siding for farm or industrial buildings. No intentional standing period was allowed for the corrugated steel siding, but 14 days elapsed between the date of construction and the date of test.

Item 10. Over the studding in panel frame No. 9, wood lath and gypsum plaster were applied in accordance with the specifications given in the next paragraph. Lath was No. 1 grade, soft pine, spaced at least ¼ in. apart and nailed to each stud with a 3*d* 16-gage wire nail. Joints were broken at every seventh course. Lath was thoroughly soaked before application and also well wetted down several hours before plastering. Wood grounds ⅞ in. thick were nailed around the stud frame and flush with the outside edges of the plates and the two outermost studs. The crevices between grounds and the panel frame were carefully calked with plastic calking compound. A seasoning period of 15 days was allowed before testing.

"Plaster shall be a good three-coat job of gypsum

plaster applied as follows: Scratch coat shall be one part plaster, hair fibered, to not more than two parts (by weight) of dry sand. Brown coat shall be of similar materials and proportions, but unfibered. The finish coat shall be four parts gypsum plaster, one part finishing lime, and five parts clean dry sand."

Item 11. After the plaster in Item 10 on Panel No. 9 was tested, a good grade of wall paper was applied. This was allowed to dry for 10 days and the panel re-tested.

Item 12. Over the studding in panel frame No. 10, metal lath and gypsum plaster were applied in accordance with the following specifications: "The metal lath shall be expanded metal lath weighing not less than 2.5 lb. per square yard, attached to each stud with 6*d* nails spaced not over 6 in. apart. Clinch of nails to be upward. Lath to be lapped at sides not less than ½ in., with lower sheet over the upper. Grounds shall be ⅞ in. as for wood lath and plaster. There shall be at least one vertical and one horizontal lap in the metal lath joint entirely across the panel.

"Gypsum plaster shall be used and applied in three coats, as follows: Scratch coat shall be one part plaster, hair fibered, to not more than two parts (by weight) of dry sand. Scratch coat shall be applied with sufficient pressure to fill all meshes and obtain good key.

"Brown coat shall be one part plaster, unfibered, to not more than two parts (by weight) of dry sand. This coat shall be kept back sufficiently from grounds to allow for finishing coat and surface shall be roughened to receive finishing coat.

"The finish coat shall be four parts gypsum plaster, one part finishing lime and five parts clean dry sand."

Item 13. Over the metal lath and plaster on panel frame No. 10 (see *Item* 12) a coat of sizing and two coats of a good commercial flat wall paint were applied. A drying period of 10 days was allowed, after which the panel was re-tested.

Item 14. The wood lath and plaster were removed from panel frame No. 9 and the stud faces carefully cleaned. Over the stud frame Insulation *A* plaster lath was applied in commercial sheets; the sheets being broken over studs twice vertically and once horizontally. Lath was nailed according to manufacturer's specifications. Grounds were ⅞ in. as for wood lath and plaster. A scratch coat and finish coat of stucco were then applied.

Item 15. The bevel siding and building paper on panel frame No. 1 were removed. Over the matched sheathing, expanded metal stucco reinforcement of 20-gage thickness with openings ¾ in. by 2 in., and weighing 1.8 lb. per square yard, was applied. Stucco reinforcement was placed horizontally and fastened to the sheathing with saddle nails spaced about 8 in. apart over the surface. Vertical laps were made over studs and horizontal laps laced with wire. Stucco was applied according to the following specifications:

"Scratch coat shall be of one part portland cement to three parts sand, applied ½ in. thick and troweled well through the reinforcement. It shall be thoroughly dry before the brown coat is applied. The brown coat shall be ½ in. thick, of the same proportions, and the finish coat from ⅛ in. to ¼ in. thick. Total thickness of stucco over sheathing shall be approximately 1⅛ in. and shall be established by 1⅛ in. grounds nailed around the outside of the stud frame." The panel was allowed to season 29 days before testing.

Item 16. The bevel siding, building paper and sheathing were removed from panel frame No. 3. Over the stud frame 1x4-in. butt-edged boards No. 2 common grade were applied spaced 5 in. on centers. Over the boards, edge grain 5/2-16-in. red cedar shingles were applied 5 in. to the weather using zinc coated shingle nails. The panel stood 69 days before testing.

Item 17. The sheathing and building paper on panel frame No. 4 were removed. Over the stud frame, 1x8-in. shiplap No. 2 common was applied butted over studs and face-nailed twice. Over the shiplap edge grain 5/2-16 in. red cedar shingles were applied 5 in. to the weather using zinc coated shingle nails. The panel stood 14 days before testing.

Item 18. The Insulation *B* standard sheathing board was removed from panel frame No. 7. Over the studs, 1x6-in. butt edged boards, No. 2 common grade were applied spaced 11 in. on centers. Over the boards, edge grain strictly clear 24-in. red cedar shingles were applied, 11 in. to weather. The panel was allowed to stand 15 days before testing.

Item 19. The corrugated sheet metal was removed from panel frame No. 6. Over the studding, 1x8 in. shiplap No. 2 common grade was applied. Over shiplap, 24-in. edge grain red cedar shingles, strictly clear, were applied, 11 in. to weather. The standing period was 14 days before testing.

Item 20. The 24-in. shingles were removed from panel frame No. 7. All remaining nails were pulled or driven flat to avoid any projections on the boards. Building Paper *B*, a good grade of paper, was then applied over boards according to manufacturer's instructions. Over the paper, strictly clear edge grain 24-in. red cedar shingles were applied 11 in. to the weather, using zinc coated nails. The panel was allowed to stand 67 days before testing.

Item 21. The 16-in. shingles were removed from panel frame No. 3. All remaining shingle nails were pulled or driven flat to avoid any projections on the boards. Building Paper *B* was then applied over the boards according to manufacturer's instructions. Over the paper, edge grain 5/2-16 in. red cedar shingles were applied 5 in. to the weather using zinc coated shingle nails. The panel stood 69 days before testing.

Item 22. The matched sheathing was removed from panel frame No. 1 and butt-edged 1x6-in. sheathing, No. 1 Common grade was applied over studs. The lumber was air dry and fitted with ordinary care. Over the sheathing, Building Paper *B* was applied according to manufacturer's specifications. Over the building paper, 1x10 red cedar bevel siding, *B* grade and better, was applied, lapped 1½-in., and double nailed with 8*d* cement-coated box nails. The panel stood for 70 days before testing.

Two coats of good quality white paint were then applied to the bevel siding at the customary intervals, and 6 days after application of the second coat the panel was re-tested.

Item 23. On the reverse side of panel frame No. 1, finished as specified in *Item* 22, wood lath and gypsum plaster were applied in conformity to specifications for

Item 10. The panel stood 68 days and was again re-tested.

Item 24. All previous construction was removed from the 2x4 studs in panel frame No. 9. Over studs air dry 1x6 No. 1 Common end and side matched sheathing was applied. The panel was allowed to stand 2 days and then tested.

Item 25. Over the sheathing in *Item* 24 ordinary red resin-sized building paper was applied with laps horizontal, nailed with No. 3 shingle nails spaced approximately 7 in. The panel was re-tested immediately.

Item 26. Over the building paper mentioned in *Item* 25, air dry 1x6 drop siding was applied, nailed in accordance with usual practice, and painted with three coats of good commercial white lead and zinc paint applied at customary intervals. The panel was allowed to season 13 days and again re-tested.

Item 27. All previous construction was removed from the 2x4 studs in panel frame No. 10. Over the studs 1x6 end and side matched sheathing was applied. The panel was allowed to season for 7 days and then tested.

Item 28. Over the other side of panel frame No. 10 corrugated steel siding was applied as in *Item* 9. The panel was re-tested four days later, the steel siding being exposed to the pressure side of test machine.

Item 29. All previous construction was removed from the 2x4 studs in panel frame No. 7. Over the studs 1x6 air dry shiplap, double nailed, Building Paper *B*, and 16 in. red cedar shingles 5/2 thickness were applied 7½ in. to the weather. The panel was allowed to season 7 days and then tested.

Item 30. Over the other side of panel frame No. 7, wood lath and plaster were applied according to the specifications of *Item* 10. The panel was allowed to season 14 days and re-tested.

Item 31. All previous construction was removed from the 2x4 studs in panel frame No. 4. Over the 2x4 studs, Building Paper *B* lapped vertical on studs, and 1x6 air dry Select drop siding were applied. Siding was painted with two coats of commercial white lead and zinc paint. After the application of final coat of paint, the panel was allowed to dry for 4 days and then tested.

Item 32. Over the other side of panel frame No. 4, 1x6 air dry end and side matched sheathing was applied. Panel was allowed to season 6 days and then re-tested.

Item 33. Drop siding and building paper (*Item* 31) were removed from panel frame No. 4 and the panel immediately re-tested with the sheathing in *Item* 32 exposed to the pressure side of the test machine.

Item 34. All previous construction was removed from panel frame No. 6, including inside vertical studs, leaving only the 2x4 plates nailed to top and bottom frame members and the two end studs nailed to vertical frame members. Between the two end studs and perpendicular to them two 2 x 4 girts were toe-nailed on 33-in. centers. Over the studs and girts and perpendicular to the latter, 1 x 10 boards were applied with a one inch space between boards and nailed with 8*d* wire nails at each side and in the middle of the boards at each girt. One heavy coat of good commercial paint was then applied. Immediately after painting, 1 x 4 battens were applied over the one inch spaces between the 1 x 10 boards and nailed on one side only of the battens through one edge of the 10-in. boards into the girts but not at other points. After the first coat of paint had dried, an additional coat was applied to boards and battens. The panel was allowed to season 14 days out-of-doors before testing.

Walker & Crocker Piping Handbook Announced

A Piping Handbook, by J. H. Walker and Sabin Crocker, of the Detroit Edison Co., the purpose of which is to provide authoritative and accessible data for the engineer interested in piping work, has recently been published by McGraw-Hill Book Co., Inc., New York.

For much of the work, no claim of originality is made by the authors. Many sources have been drawn upon freely with the idea of assembling and co-ordinating all appropriate material. Due credit to the original sources of extracted material has been carefuly given throughout the book. Certain specialized subjects, including heat insulation, water supply piping, oil piping and gas piping, have been ably handled by other contributors, each of whom is a recognized authority in his particular field. Particular attention is called to Chapter VII on Expansion and Flexibility. This subject, which has engaged the attention of numerous investigators, is fully covered, and simple methods are given for computing the expansion stresses and anchor thrusts in pipe lines.

Boiler Scale Investigation

Engineering Experiment Station Project 103, "A Study of the Causes of Adherence of Scale in Steam Boilers," is being carried on by Professor C. W. Foulk of the department of chemistry of Ohio State University, assisted by Joseph L. Gillman.

An experimental pressure boiler has been presented for this investigation. The boiler is of the horizontal water tube type, having a single tube of about 1.5 sq. ft. of heating surface. The drum is constructed of 4-in. double extra heavy pipe which has been drilled and tapped at suitable points for a pressure gage, feed water connection, safety valve, and steam outlet. A system of treating and handling the feed water with the aid of an electrically driven chemical proportioning pump has been designed and is being installed. The water level is determined by means of a gage glass. The boiler is heated by a gas-fired furnace, mounted as a single unit and enclosed by standard steel channel sections at top and bottom and steel sheets at the sides.

Japanese Translate U. S. Mines Paper

An interesting instance of foreign appreciation of the value of a United States Government publication is the recent printing of a Japanese translation of Technical Paper 80, "Hand Firing Soft Coal Under Power-Plant Boilers" of the United States Bureau of Mines, Department of Commerce. Sojiro Haga, chief engineer and engineering director of the First Engine and Boiler Insurance Company, Ltd., of Tokyo, has transmitted a copy of the Japanese edition of the paper to Scott Turner, Director of the Bureau of Mines, with the statement that, in his opinion, the paper admirably meets the needs of boiler attendants in Japan.

Technical Paper 80, which was written by Henry Kreisinger, contains descriptions of methods of firing soft coal under power-plant boilers and of methods of handling fire so as to have the least smoke and to get the most heat from the fuel. The paper seeks to meet the needs of the firemen employed in plants using small units aggregating 1000 to 2000 horsepower capacity, many of these firemen lacking a technical education. For this reason the pamphlet has been written in plain and simple language, technical terms having been avoided as far as possible. Technical Paper 80 has run through several editions and obtained a circulation of many thousands of copies in the United States.

Economic Use of Steam in Modern Buildings

By F. A. Gunther[1], Pittsburgh
MEMBER

RAPID progress has been made and is being made toward the simplification and perfection of the modern steam heating system, and yet with all the available highly efficient apparatus, very little has been accomplished in the reduction of overheating of modern buildings. The desirability of elimination of any wasteful practice is, of course, admitted. From the standpoint of cost, the building owner is much interested and from the standpoint of conservation of mineral resources there is again much favorable argument. Also from the standpoint of health, anything that can be done toward increasing resistance to colds and other respiratory diseases should certainly receive consideration.

The essentials for heating modern buildings must be kept clearly in mind before attempting to predict or state the magnitude of overheating of any building or group of buildings. Probably the three most important features of a satisfactory heating system are:

1. Proper distribution of the sources of heat within the space to be heated.
2. Sufficient and continuous supply of good air.
3. Regulation of temperatures within the comfort zone.

With these three essentials properly taken care of, much can be done toward properly and economically operating a heating system. The building operator must learn where the heat supplied to the building is consumed. He should be taught that any building is considerably like a sponge or sieve, soaking up heat and dissipating it through a myriad of heat leaks. Warm air is lost from the building through cracks around window sash and frames and through the walls themselves. Heat is conducted through the walls and glass and radiated from these wall and glass surfaces of the building. The chimney effect should be thoroughly explained to him, which should show him why more heat must be supplied to the lower floors of the tall building and less to the upper floors. In any existing building, very little can be done to reduce the conduction and radiation losses; but on the other hand, large losses due to excessive air change can be eliminated by proper caulking and weather-stripping of all openings.

With this much of the problem realized, the answer becomes tangible. Assuming that the construction of any particular building is known and the defects kept in mind, it becomes necessary to next find out what consumption of fuel should be expected to properly and economically heat the building. Much arugment has resulted concerning the basis of comparison of heating consumption. Some engineers insist on comparing consumption on the basis of pounds of steam per cubic foot of volume. Others insist that the proper comparison should be on the basis of pounds of steam per square foot of equivalent direct radiation. The latter, in the writer's opinion, is preferable, especially when one realizes that in buildings of today the radiation has been designed to carry a temperature of 70 degrees for a certain minimum outside temperature and wind condition, and that the calculations include the amount of heat necessary to take care of a specified number of air changes per hour. Therefore, when comparing heat consumptions on the basis of pounds of steam per square foot of equivalent direct radiation, the figures include not only radiation and conduction losses from the building, but also take into consideration the net volume of the building for the purpose of air change.

For many years, operators have been assuming that because any certain existing building consumes, for instance, 500 lb. of steam per square foot of equivalent direct radiation that it is being heated properly, that there is not too much overheating and yet a figure as high as this may show as much as 50 per cent excessive consumption due entirely to this one cause. The figure may be entirely correct and basically economical for a warehouse, but for an office building with indirect or semi-indirect illumination and average occupancy, the heat from these two latter sources plus the other minor sources of heat in the building, exclusive of the heating system itself, this figure is usually nearly twice too high. When proper credit has been given for heat supplied by lights, occupants, domestic hot water systems, risers, and other miscellaneous minor sources of heat, this figure becomes less than 300 lb. per square foot per season. This does not mean that any building now using more than 500 lb. can be cut to 300 lb. and all parts of the building properly heated, because there are innumerable exceptions. On the other hand, the writer made a survey and analysis of over eighteen buildings in Pittsburgh which do not control the supply of steam with any extra intention toward economy and has found that the average amount of steam used by these buildings was 572 lb. per cubic foot per average season. Yet, a number of these buildings are now being heated for less than 350 lb. and heated quite satisfactorily.

For the building operator to determine what the fuel or steam consumption for any existing building should be, it is necessary first to make a few simple tests. First, the cooling rate for the building should be determined

[1] Sales Engineer, Direct Control Valve Co., Pittsburgh, Pa.

For presentation at the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Minneapolis, Minn., June 1930.

by taking indoor temperatures over a period of time with no steam turned into the radiators of the building. This should be done for several out-door temperatures. These tests should be repeated at the same out-door temperatures with different wind velocities. Similar data should be taken to obtain the rate at which the building can be reheated after it has cooled. With these data available, it will be quite simple to plot curves between the coordinates of time and out-door temperature and Some idea of the proportionate savings by shutting off steam at night may be realized from comparison of area *A* with area *B*. Under the dotted line on the steam consumption portion of the chart is shown the amount of steam which would be consumed if the steam had not been shut off at night and the temperature had been maintained at the day-time level.

For the purpose of checking day consumptions the operator can plot the results obtained by dividing the

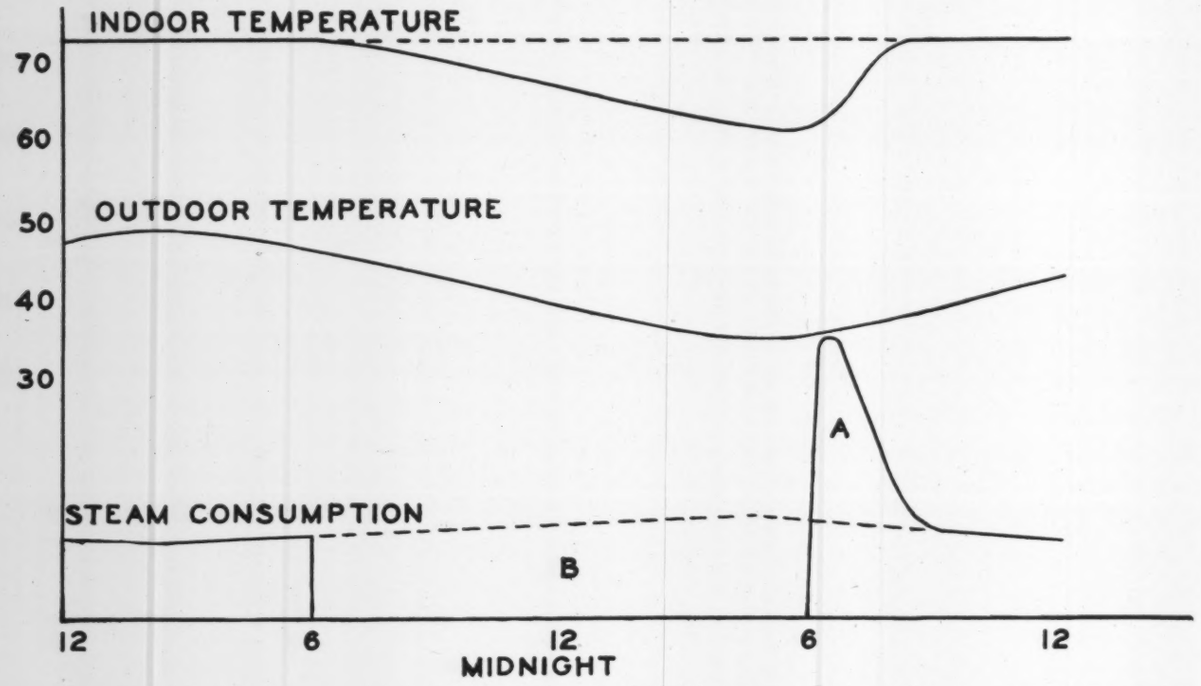


Fig. 1—Indoor Temperature and Steam Consumption for a Typical Building on an Average Day With Steam Off During the Night Hours

correcting factors for wind velocity which will indicate at a glance at what time steam may be shut off a building in the evening and should be turned on in the morning. One or two readings taken at specified hours during the night will serve as a check on these curves and allow proper corrections to be made for excessive drops in indoor temperature due to any change in out-door weather conditions. In addition, accurate data can be taken on the amount of fuel necessary to maintain average indoor temperatures by following the indications given by the results of these tests. Considerable of the wastage of steam during the night hours when the building is not occupied can be eliminated in this manner. A large amount of discussion has prevailed as to whether or not it is practical to save fuel at night, but any one who has operated a building and made tests with and without shutting off steam during the night hours, knows that it is usually possible to save fuel by shutting off the supply of steam at night.

Fig. 1 illustrates theoretically what might be expected in the cooling of a building after the steam has been shut off on an average winter night. Indoor and out-door temperatures are both shown. The heating-up period for this day for an average building completely equipped with automatic temperature control requires about two hours. At the bottom is shown the steam consumption. daily steam consumption by the number of square feet of equivalent direct radiation in use and this quantity by a number of degree-days for that particular day and plotting this amount against the number of degree-days per day. The resultant average curve drawn through these points should be hyperbolic and resemble that shown in Fig. 2. To properly regulate the temperature of a building during the hours of occupancy requires considerable attention on the part of the operator, yet it has been the writer's experience that the time spent is returned in dollars and cents many times over.

The supply of heat must at all times be adequate to keep the tenants satisfied, and stinting may result in extra work for the renting agent. On the other hand, a too liberal supply of heat is just as unsatisfactory and will result in a large number of open windows. Even without automatic control of temperatures both day and night it is possible, as previously stated, to reduce the fuel consumption to a degree. But from the vast amount of data now available, it appears that more can be accomplished by installing automatic temperature control equipment in the existing buildings and insisting upon its installation in the new buildings. There are a large number of automatic control devices manufactured today, each of which has its various points of advantage. These devices can be classified in two groups. *First,* those which control

the temperature of the agent or medium of heat distribution and *second*, those which control the supply or quantity of the agent or medium. The second group can be further divided as follows:

1. Unit thermostatic control obtained through the use of one automatic thermostat controlling the supply to the entire building.
2. An amplification of (1) or what is known today as the automatically controlled zone system.

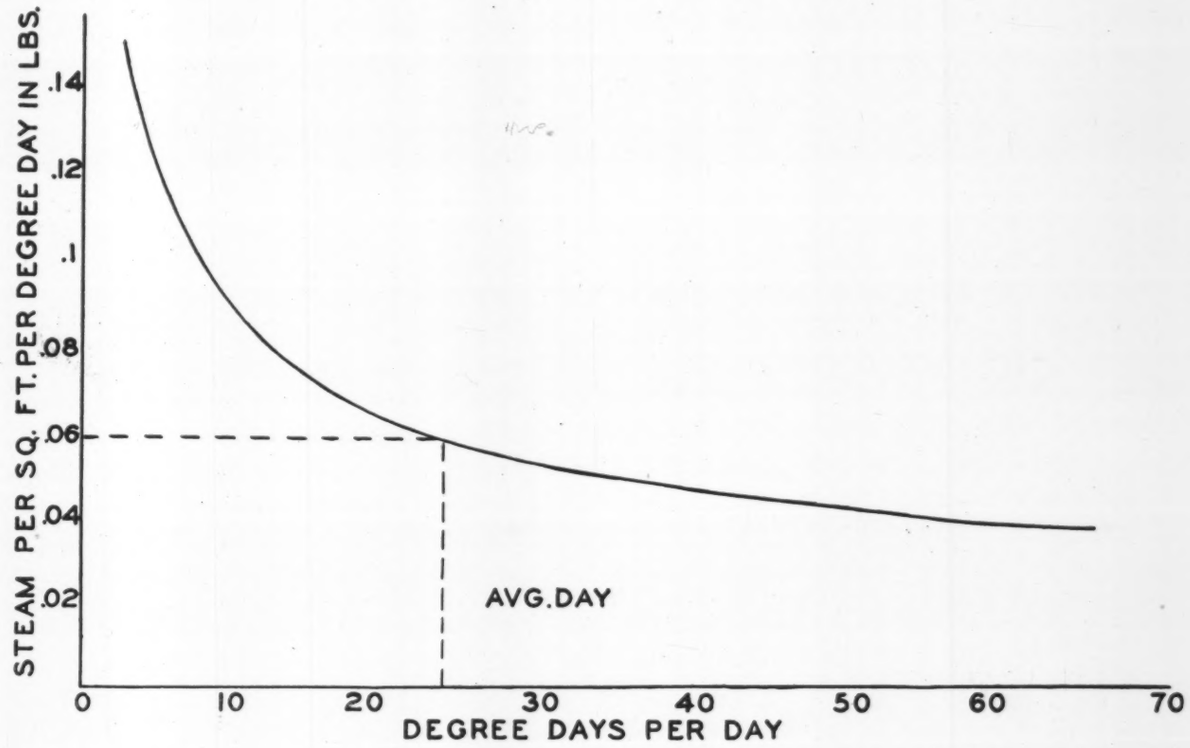


FIG. 2—TYPICAL HEATING RATE CURVE

3. The more efficient result obtained from controlling groups of radiators.
4. The single radiator control.

The question has been often asked—What is good automatic temperature regulation? It is the maintenance of any specified temperature continuously, accurately, and automatically, and involves an automatic apparatus that supplies just the amount of heat necessary for the individual room it is controlling and no more. When this control is established throughout the building there will be consumed only that amount of fuel necessary to properly heat the building—any less is stinting; any more is wasteful. While this is a fundamental theorem, yet it is quite probable that it includes the whole truth about automatic temperature control.

The engineer of today designing buildings for tomorrow is neglecting his duty if he does not use every effort to include in his specifications the best type of automatic temperature control. Nor will he be quickly forgiven for this omission by the owner and future builder who are rapidly learning the great advantages to be obtained from a comparatively small addition to the initial cost of their buildings in the addition of this type of equipment.

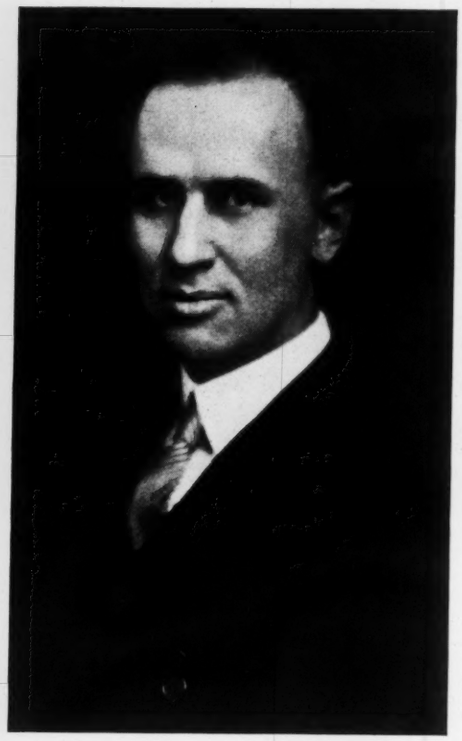
Most of us have been guilty of installing radiation on courts and light-wells, assuming the same need for heat to be supplied to these locations as exists in the rooms with outside walls. Recent data show that the steam consumption of court radiation is approximately one-half that of outside radiation when calculated on the same basis. More information is needed to make a thorough determination along this line but certainly too much radiation has been used in the inside court rooms.

Engineers have been accustomed to figuring indirect radiation equivalent to direct radiation in ratios of from two to one, to seven to one, and yet the steam consumption of indirect systems rarely shows more than an average of one and one-half to one.

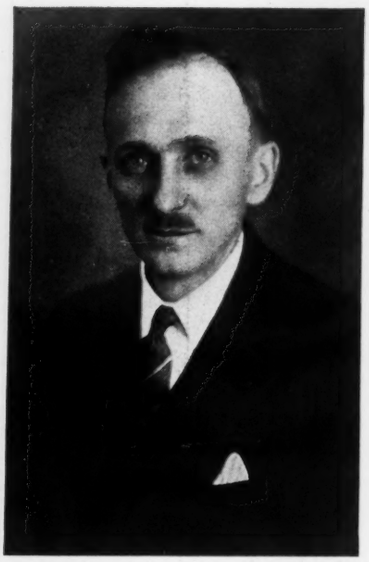
In the article entitled The Effect of Two Types of Cast-Iron Steam Radiators on Air Temperatures in Room Heating, by A. C. Willard and M. K. Fahnestock, which appeared in the March 1930 issue of *Heating, Piping and Air Conditioning,* the fallacy was pointed out of taking room temperatures 5 ft. above the floor and yet nearly all heating specifications insist that temperatures be taken at this elevation.

Looking back over the past 15 years, considerable progress has been made in designing more efficient and more satisfactory systems of heating and ventilating. The next 15 years will, no doubt, bring forth even more improvements, and the writer predicts that the heating system of the near future will be not only more efficient, but will give greater satisfaction, will be entirely pleasing to the eye—rather more of a decoration, easy to keep clean and completely and automatically controlled. Positive and forced ventilating will be included as being as necessary as the supply of heat and the air will be really conditioned instead of just strained.

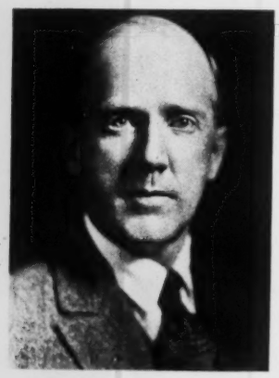
E. F. Jones, President
Minnesota Chapter



Albert Buenger, Chairman
Committee on Arrangements



M. S. Wunderlich, Secretary
Minnesota Chapter



D. M. Forfar,
Vice-President
Minnesota
Chapter

W. F. Uhl,
Chairman
Hotel and Transportation
Committee

Frank B. Rowley, Second Vice-President, A. S. H. V. E., Chairman, Reception and Registration Committee

Mrs. Frank B. Rowley,
Chairman
Ladies' Entertainment
Committee

THIRD AVENUE BRIDGE LOOKING TOWARD MILLING DISTRICT AND BUSINESS SECTION OF MINNEAPOLIS

Society's Biggest Summer Meeting in Prospect

Minneapolis Ready for A. S. H. V. E. Members June 24-27

THE last week in June will see the pioneer movement of A. S. H. V. E. members to the Land-of-the-Lakes, where the Semi-Annual Meeting of the Society will be held during the four days, June 24-27, at the Curtis Hotel, Minneapolis. The trek westward, northward or eastward, as the case may be, to Minneapolis will be far different from pioneer days when the first settlement at the Falls of St. Anthony was made.

Minneapolis, with its numerous lakes, wide and tree-lined streets, boulevards and parks, is a pretty setting for the Summer Meeting, and those members who travel by train, automobile or plane will visit a delightful part of the country and find the trip worth while from every standpoint.

A splendid technical program has been planned and three papers will be given each day at the technical sessions, in the ballroom of the Curtis Hotel, which will be held each morning from 9:30 a. m. to 12:30 p. m.

The work of the Committee on Arrangements and the various sub-committees of the Minnesota Chapter indicates that the hours for recreation and entertainment will be well filled.

Everything possible has been done in advance and the visiting members are assured of a delightful visit with their Minnesota hosts.

Of great importance to members visiting Minneapolis is the reduced fare arrangement granted by the railroads. Under the regulations this year, identification certificates will be sent to each member from the headquarter's office of the Society, and when this certificate is presented to the railroad ticket agent the round trip ticket at fare and one-half may be purchased.

One certificate is sufficient for the entire family.

The tickets issued at fare and one-half under the identification certificate plan may be used within certain limit dates. Should any of the members desire to make this trip a vacation event, they are privileged to buy tickets with a 30-day return limit at the rate of fare and three-fifths.

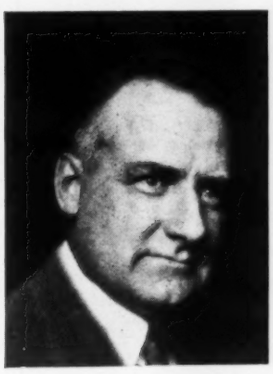
It is important that members read the rules regarding certificates:

Reduced Fare Regulations

Round trip identification certificates for the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Minneapolis, Minn., June 24-27, 1930, will be issued to members from the office of the secretary prior to June 1.

These identification certificates, printed on special safety paper,

A. J. HUCH, CHAIRMAN
PUBLICITY COMMITTEE



H. E. GERRISH, CHAIRMAN
ENTERTAINMENT COMMITTEE

H. J. SPERZEL, CHAIRMAN
GOLF COMMITTEE

A. M. WAGNER, CHAIRMAN
FINANCE COMMITTEE

PROGRAM

36th Semi-Annual Meeting

American Society of Heating and Ventilating Engineers

Curtis Hotel June 24-27, 1930 Minneapolis, Minn.

TECHNICAL

JUNE 24

Tuesday —A.M.

8:30—Registration, Curtis Hotel.

9:30—Greeting by E. A. Jones, *President* Minnesota Chapter.

Response by Pres. L. A. Harding.

Report of Committee on Meeting Programs, A. C. Willard, *Chairman.*

Control Equipment for Gas Burning Heating Appliances, by W. E. Stark.

Economic Use of Steam in Modern Buildings, by F. A. Gunther.

Report of Guide Publication Committee, D. S. Boyden, *Chairman.*

JUNE 25

Wednesday—A.M.

9:30—Report of Committee on Research, F. B. Rowley, *Chairman.*

Report of Director of Research Laboratory, F. C. Houghten.

Surface Conductances as Affected by Air Velocity and Character of Surface, by F. B. Rowley, A. B. Algren, and J. L. Blackshaw.

Wall Surface Temperatures, by A. C. Willard and A. P. Kratz.

How Comfort Is Affected by Surface Temperatures and Insulation, by Paul D. Close.

JUNE 26

Thursday— A.M.

9:30—Report of Committee on Oil Burning Devices, L. E. Seeley, *Chairman.*

Report of Committee on Pipe Sizes for Heating Systems, H. M. Hart, *Chairman.*

Capacity of Return Mains for Gravity and Vacuum Steam Heating Systems, by F. C. Houghten and Carl Gutberlet.

Loss of Head in Submerged Orifices, by F. E. Giesecke.

Air Infiltration Through Various Types of Wood Frame Building Construction, by G. L. Larson, D. W. Nelson, and C. Braatz.

JUNE 27

Friday —A.M.

9:30—The Application of Air Conditioning to Premature Nurseries in Hospitals, by C. P. Yaglou, Philip Drinker and K. D. Blackfan (Presentation by W. H. Carrier).

Report of Committee on Garage Ventilation, E. K. Campbell, *Chairman.*

Carbon Monoxide Concentration in Garages, by A. S. Langsdorf and R. R. Tucker.

Report of Committee on Air Cleaning Devices, O. W. Armspach, *Chairman.*

Report of Nominating Committee.

ENTERTAINMENT

Monday— A.M.—Headquarters, Reception Committee—LaSalle Hotel, Chicago, Illinois.

P.M.—Reception of Guests by Committee—Curtis Hotel, Minneapolis, Minn.

Tuesday— A.M.—Curtis Hotel.

8:30—Registration—Lobby floor.

9:30—12:30—Technical Session—Ball Room, Curtis Hotel.

11:30—Luncheon for Ladies.

P.M.

2:00—Sightseeing and Inspection (Twin Cities and U. of Minn., Engrg. Lab., Plant of Minneapolis—Honeywell.)

7:00—Council Dinner and Meeting.

8:30—Informal Reception and Dance, Curtis Hotel Ball Room.

Wednesday—A.M.

9:30—12:30—Technical Session—Ball Room, Curtis Hotel.

10:30—Ladies' Shopping Tour.

P.M.

2:00—Golf Tournament—Minneapolis Automobile Club. (Research Cup)
Ladies' Golf Match—Automobile Club.
Bridge and Tea for Ladies—Automobile Club.

7:00—Informal Dinner for Members and Ladies.

Thursday— A.M.

9:30—12:30—Technical Session—Ball Room, Curtis Hotel.

P.M.

1:30—Garden Party for Ladies.

2:00—Golf Meet (Kicker's Handicap) Thorp Country Club.

7:00—Semi-annual Banquet and Dance, Curtis Hotel Ball Room.

Friday— A.M.

9:30—12:30—Technical Session.

12:30—Hostess Luncheon for Ladies.

AIRPLANE VIEW, UNIVERSITY OF MINNESOTA

RATES

CURTIS HOTEL

Room and bath, one person—$2, $2.50 and $3 per day.

Room and bath, two persons—$3, $3.50 and $4 per day.

Room and bath (twin beds)—$4.50, $5 and $6 per day.

Parlor suites—$7 to $12 per day.

must be presented to the local ticket agent when buying round trip tickets to Minneapolis at fare and one-half. Identification certificates will be honored upon presentation of one certificate for the Society member and the members of his family and tickets purchased thereon will be good via the same route in both directions within the time limit specified by the Passenger Associations.

Tickets will be sold on the dates shown in the accompanying table with final return limit to reach original starting point not later than midnight of date specified:

		Dates of Sale	Return Limit
Western and Transcontinental Territory			
Colorado (Julesburg only)	Missouri		
Illinois	Nebraska		
Iowa	Northern Michigan		
Kansas	North Dakota	June 20-26	July 3
Manitoba	South Dakota		
Minnesota	Wisconsin		
Colorado (except Julesburg)	Wyoming		
New Mexico		June 19-25	July 4
Montana	Utah		
Southern Idaho		June 18-24	July 5
*Arizona	*Oregon (except via		
*British Columbia	California)	June 18-24	July 6
*Nevada			
*Northern Idaho	*Washington		
*California		June 17-23	July 6
*Oregon (via California)		June 16-22	July 6
Southwestern Territory			
Oklahoma	Texas	June 19-25	July 4
Arkansas	Missouri		
Kansas	Memphis, Tenn.	June 20-26	July 3
Louisiana	Natchez, Miss.		
Central Territory			
Illinois	New York (west of		
Kentucky	Buffalo)		
Indiana	Ohio		
West Virginia	Michigan	June 20-26	July 3
Pennsylvania (from Pittsburgh and Washington)			
Points on Mississippi River from Keokuk, Ia. to Cairo, Ill., for traffic through Illinois			
Ontario, Canada, on lines of Mich. Cent., Pere Marquette and Wabash R. R.			
Eastern and Southeastern Territory			
New York (to Buffalo)	Georgia		
Pennsylvania (east of Pittsbgh).	Florida		
New Jersey	Alabama	June 20-26	July 3
Delaware	Mississippi		
Maryland	Tennessee		
Virginia	(to Memphis)		
West Virginia (to Kenova)	Kentucky (to		
District of Columbia	Louisville)		
North Carolina			
South Carolina			
New England Territory			
Massachusetts	Vermont		
Connecticut	Maine	June 19-25	July 3
New Hampshire	Rhode Island		
Canadian Territory			
Eastern and Western Provinces covered by Canadian Passenger Association			

*Round trip summer tourist fares *lower* than 1½ fare certificate plan.

Tickets must be presented at destination (in this case, Minneapolis) and validated by ticket agents at regular offices of the lines over which the ticket reads and, when validated, will be good for return trip leaving place of meeting on any date within the final return limit, but passenger must reach original starting point prior to midnight of such final limit.

When presenting certificate to purchase ticket, the name of the member to whom certificate is issued and the names of the dependent members of his or her family, if more than one ticket is purchased, should be filled in before presentation of the identification certificate to the local ticket agent.

Members should purchase their tickets at least 30 minutes before train departure.

Failure to have return ticket stamped by railroad agent before boarding train may cause embarrassment and require payment of additional fare.

LOOKING DOWN NICOLLET AVENUE

A. S. H. V. E. PIONEER DINNER

Prepared under the personal direction of GEORGE RECTOR

Monday, June 23, 1930

Celery Hearts — **Iced Radishes**

Puree Mongole — **Consomme—Brunoise**

Filet of Lake Superior Whitefish Meunier

Grilled Dinner Steak "Milwaukee"

Roast Philadelphia Capon a l'Anglaise

Red Raspberry Sherbet

Long Branch Potatoes — **New Peas, au Beurre**

Olympian Salad French Dressing

French Vanilla Ice Cream — **Pecanesques**

Green Grapes

Old English Cheese

Toasted Crackers

Dinner Rolls

Coffee

ONE DOLLAR AND FIFTY CENTS

In addition to round-trip fare on basis of *fare and one-half*, railroads have also authorized round-trip tickets on the basis of *fare and three-fifths* with a return limit of 30 days from date of sale.

Members must specify when purchasing round-trip tickets which basis of fare is desired—fare and one-half with limited return dates or fare and three-fifths with 30 day return limit.

Members from Arizona, Nevada, Washington, Oregon, California, Idaho and British Columbia should buy round-trip tickets at summer tourist rates, which are on a lower basis than round-trip identification certificate plan fares.

For the convenience of members, special cars from the various chapter cities will be routed through Chicago and at that point a special train will leave Union Station over the Milwaukee Road at 6:30 p. m. (central standard time) June 23.

This A. S. H. V. E. Pioneer Special will consist of baggage and club car, standard roller-bearing Pullman sleeping cars, two dining-cars and an observation car.

THE CURTIS HOTEL

A special dinner will be served on this train under the personal direction of George Rector, whose fame as a caterer is world-wide.

For those members who spend Monday in Chicago, facilities have been provided at the Hotel LaSalle for reception and rest-rooms in charge of the Minnesota Chapter Reception Committee and, through the co-operation of the Illinois Chapter, golfing privileges at various clubs in Chicago will be provided for visiting members who desire to work out in preparation for the golf tournaments at Minneapolis. Arrangements for the ladies to visit Chicago stores have also been provided.

The members received a booklet describing Minneapolis in which they found a return postcard which would bring them information from the Transportation Committee on road conditions or train schedules to Minneapolis.

W. F. Uhl has the important assignment of providing information about transportation and also the very important work of arranging for an automobile sight-seeing tour of the Twin Cities, which will include inspection stops at the Engineering Experiment Station of the University of Minnesota and the new plant of the Minneapolis-Honeywell.

Registration for the meeting will commence at the headquarters in the Curtis Hotel, at 8:30 a. m., Tuesday, June 24, and it is expected that 500 members and guests will be present.

The complete technical and entertainment programs are given on a following page and it should be noted that ample time is assigned for discussion of papers and reports. The papers are on subjects of unusual interest and should develop valuable discussions.

Great interest is apparent in this first meeting in the Land-of-the-Lakes at the gateway to the Northwest, and our Minnesota hosts anticipate with pleasure the coming of a large crowd.

The June slogan for A. S. H. V. E. members is, "Meet Me in Minneapolis."

COMMITTEES

General Arrangements Committee

A. Buenger, *Chairman*

H. E. Gerrish — H. J. Sperzel
A. J. Huch — W. F. Uhl
F. B. Rowley — A. M. Wagner

Reception and Registration Committee

F. B. Rowley, *Chairman*

N. D. Adams — C. E. Hasey
W. B. Clarkson — L. C. Hanson
S. A. Challman — E. F. Jones
G. A. Dahlstrom — J. V. Martenis
Charles Foster — A. H. Probst
E. B. Gordon, Jr. — A. L. Sanford
M. S. Wunderlich

Hotel and Transportation Committee

W. F. Uhl, *Chairman*

J. H. Brown — H. G. Helstrom
E. J. Burns — W. N. Parks
M. H. Bjerken — F. C. Winterer

Entertainment Committee

H. E. Gerrish, *Chairman*

H. H. Bradford — A. J. Huch
C. G. Burritt — R. B. Mosher

Finance Committee

A. M. Wagner, *Chairman*

E. F. Jones — G. C. Morgan
R. W. Otto

Publicity Committee

A. J. Huch, *Chairman*

C. E. Gausman — Fred Shernbeck
C. E. Hill — E. J. Uhl

Golf Committee

H. J. Sperzel, *Chairman*

D. M. Forfar — J. B. Harris
D. C. Ruff

Ladies and Hostesses Committee

Mrs. F. B. Rowley, *Chairman*

Local Chapter Reports

Cleveland

April 17, 1930. This meeting was held in the rooms of the Cleveland Engineering Society, Carnegie Hall, the principal speaker of the evening being Prof. A. P. Kratz of the University of Illinois. T. J. Duffield, Executive Secretary of the Committee on Research, was present as a guest.

Professor Kratz gave an interesting illustrated lecture on *The Progress of Research,* and discussed results obtained at the University of Illinois during investigations of various types of heating systems. Experimental work done in the Warm Air Research Residence was also described fully. Other research work carried on at the University was reviewed, which was followed by a discussion by the members present.

Illinois

April 14, 1930. The regular meeting of the Illinois Chapter of the Society was held on April 14, at the Hotel Sherman, with an attendance of 54 members and guests.

Secretary DeLand read the minutes of the March meeting, which were approved as read.

H. G. Thomas spoke of the heroic death of E. J. Deane of the Hotel Sherman staff, who had long been associated with the Chapter dinners. It was voted that the Chapter, in an appropriate manner, express their sympathy to Mr. Deane's family, and it was voted to send flowers. The death of William G. Snow, one of the past presidents of the Society, was also announced by President Thomas.

After a brief discussion on the Summer Meeting the representatives for the C. & N. W. and the C. M. St. P. & P. described their facilities and service.

An announcement was made that the boiler code revision had passed ten to one.

On motion by John Howatt, seconded by H. M. Hart, it was voted to hold a chapter golf tournament at Glen Oak.

Prof. F. B. Rowley of the University of Minnesota was then introduced as the speaker of the evening by John Howatt. Professor Rowley gave an interesting talk on the Society and its Research Activities, which was thoroughly enjoyed by all. A rising vote of thanks was given to Professor Rowley at the conclusion of his address, which was followed by adjournment.

Kansas City

April 14, 1930. Thirty-five members and guests of the Kansas City Chapter met at the Ambassador Hotel on April 14, for the regular monthly meeting of the Chapter.

After the usual order of business was taken care of, the presiding officer, President Clegg, turned the meeting over to F. C. Houghten, director of the Research Laboratory of the Society.

Mr. Houghten outlined the growth of the Research Laboratory and the manner in which the various problems that come up before the Laboratory staff are handled. After discussing the Laboratory at length, he then proceeded to consider some of the major subjects, such as radiation and heat transmission, illustrating his remarks with slides showing the curves and views of work now being conducted at the Laboratory.

A hearty vote of thanks was extended to Mr. Houghten in appreciation of his visit to the Chapter and for his interesting address which brought about much discussion.

About 10 p. m. the meeting was adjourned.

Minnesota

April 14, 1930. Members and friends of the Minnesota Chapter of the Society met at Rochester, Minn., on the afternoon of April 14, and were conducted through St. Mary's Hospital, after which they inspected the new Mayo Clinic Building, the tunnel system of the clinic and corporation buildings, the service tunnels and the heating station.

Albert Buenger and Neil Adams arranged a very unique idea for dinner, which was served in a new furnace that was recently installed in the Franklin heating station.

A. J. Lobb, in behalf of the Mayo Clinic and the Kahler Corp., owners of the station, welcomed the members and guests. He brought out the point that as a rule engineers do not mix in with community activities or politics because of their special training. He then urged them to try to get into public life more.

Mr. Adams addressed the gathering, giving a description of the Franklin plant and its equipment. He also called attention to the paper written by Pres. L. A. Harding, entitled Power from Process and Space Heating System, which was presented before the Society at its Annual Meeting in Philadelphia. The Franklin plant, Mr. Adams stated, has been in successful operation for two years, and was designed on the principles outlined in President Harding's paper.

The secretary of the Society, A. V. Hutchinson, was then called upon, and he gave a brief talk on the forthcoming summer meeting to be held in Minneapolis, June 24 to 27, urging every member to do his best to make it a success.

Thirty-four men attended the meeting and 25 were able to sit down to dinner inside of the furnace, as shown by the accompanying illustration.

DINNER SERVED IN FURNACE TO MINNESOTA CHAPTER

Michigan

April 14, 1930. The meeting held by the Michigan Chapter of the Society on Monday evening, April 14, proved to be unusual in many respects. There were 110 members and guests present to hear W. H. Carrier, second vice-president of the Society, speak on Home Humidification.

Due to the fact that the *National Warm Air Heating Association* was holding its annual convention in Detroit at this time, the Michigan Chapter was fortunate to have as guests J. M. Triggs, Huntington, Ind., president; H. T. Richardson, New York, first vice-president; A. W. Williams, Columbus, O., secretary; and E. B. Langenberg, St. Louis; J. F. Firestone, Chicago; Prof. J. D. Hoffman, Purdue University; Prof. A. P. Kratz, University of Illinois; A. V. Hutchinson, secretary of the Society; W. H. Patchell, consulting engineer of London, England, and Dr. H. L. Simpson of Detroit.

After Pres. W. G. Boales had introduced the guests of the evening, reports were heard from the treasurer, R. K. Milward, and from W. J. Whelan, chairman of the Program Committee. At this time President Boales announced to the Chapter the death of William E. Foster, who died on March 8.

The president then appointed the nominating committee, consisting of J. H. Walker, chairman; J. F. McIntire and Edward Harrigan, requesting that the Nominating Committee prepare a slate of the officers for the coming year to be voted upon at the May meeting.

W. H. Carrier was then introduced. He discussed in detail heating, ventilation and air conditioning, particularly the effect of temperature and humidity on the comfort of human beings. He then presented a few pictures of the air conditioning system which has been recently installed in the U. S. Capitol in Washington, D. C.

Mr. Carrier's interesting presentation was followed by remarks from Dr. Simpson, Detroit, an eye, ear, nose and throat specialist, who complimented the Society on the work which it is doing from the standpoint of health and maintenance of health, particularly referring to the absolute necessity of having the proper temperature and relative humidity in the home.

It was with regret that the Chapter announced that Pres. W. G. Boales, who has been an outstanding figure in the Chapter for five years, was leaving Detroit to make his home in Columbus, Ohio. It was also announced that the credit of bringing the Michigan Chapter to the position which it occupies today is largely due to President Boales.

The meeting was brought to a close about 11 p. m.

New York

April 21, 1930. The Nash Engineering Co., South Norwalk, Conn., were hosts to the New York Chapter on the occasion of the annual inspection trip.

The party made the trip from New York in a special car and immediately upon arrival at the plant of the Nash Engineering Co., refreshments were served, after which the delegates were divided into groups of nine each and taken on a tour of inspection of the plant. The inspection tour required more than an hour, and was most instructive. The manufacturing methods of the Nash Engineering Co. were described in detail by the guides, and a thorough description was thereby conveyed to the visitors of the precision required by the Nash organization in the manufacture of its products.

After the inspection tour, a sumptuous shore dinner was served, after which the regular Chapter meeting was held. The reports of the Secretary and Treasurer were presented, and the ballots for the officers for the 1930-31 season were counted. The following officers were elected:

President, A. J. Offner.
Vice-President, Russell Donnelly.
Treasurer, F. E. W. Beebe.
Secretary, W. A. Swain.
Board of Governors, E. J. Ritchie,
A. L. Baum, and G. G. Schmidt.

Mr. Johnson, retiring secretary, was presented with a pair of gold cuff links as a token of appreciation for the nine years he served the Chapter as secretary.

A rising vote of thanks was given to Mr. Jennings, president of the Nash Engineering Co., for the hospitality extended to the Chapter.

New York Chapter Inspection Trip to Nash Engineering Co. Plant, South Norwalk, Conn., April 21, 1930.

Pacific Northwest

April 24, 1930. The meeting was held in the gold room of the New Washington Hotel, President E. L. Weber presiding.

Following the usual dinner, Professor Daniels of the University of Washington, gave an interesting talk on fuel consumption and supply, especially as it concerns the State of Washington. Mr. Montgomery of the U. S. Ozone Co. then submitted the history and progress of ionization as it pertains to air conditioning.

The Smoke Committee reported progress on the smoke ordinances. Reports of the Membership Committee and the Nominating Committee were submitted.

The following officers were nominated for the ensuing year:

President—E. O. Eastwood.
Vice President—C. Twist.
Secretary—M. Anderson.
Treasurer—W. W. Cox.
Board of Governors—W. E. Beggs, E. L. Weber, L. Dudley.

Mr. Barringer, Chief Boiler Inspector, discussed the proposed new code as regards welding, and the following committee was appointed to confer with him: L. Dudley, W. E. Beggs, M. Anderson.

Philadelphia

May 8, 1930. The annual outing meeting of the Philadelphia Chapter was held beginning at noon at the Torresdale-Frankford Country Club. During the afternoon, about fifty golfers enjoyed the beautiful course and the hospitality of the Torresdale-Frankford Club, after which dinner was served at the Club House, with approximately 100 members and guests in attendance.

After the dinner, the Chapter made a tour of inspection of the John J. Nesbitt Co. Plant. The entire shop was in full operation during this inspection, and the various processes involved in the manufacture of unit ventilators was explained by competent guides and members of the engineering staff of the company. A resolution was adopted thanking the John J. Nesbitt Co. for their courtesy.

After the inspection, a brief business session was held, beginning with the reading of the minutes of the previous meeting by the Secretary, and the report of the Treasurer, both of which were accepted without correction. M. F. Blankin, Chairman of the Meetings Committee, then gave a brief report of the activities of the Chapter during the past year, and outlined a tentative schedule for the next year.

April 10, 1930. H. S. Christman of the Philadelphia Gas Works Co. was the speaker of the evening and gave a most able and interesting talk on the subject, House Heating with Gas. This talk was very well presented and thoroughly enjoyed by all the members present. At the conclusion, a lively discussion followed, after which a rising vote of thanks was extended Mr. Christman.

This was one of the most interesting and best attended meetings of the Chapter in recent years, 92 being present for the dinner preceding the meeting, while 112 members and guests were present for the meeting and discussion of the paper presented by Mr. Christman.

Upon motion by Ray Bolsinger, which was properly seconded, the following members were elected as the Nominating Committee for 1931: A. C. Edgar, *Chairman;* F. D. Mensing, S. E. Plewes, A. W. Luck and A. McClintock, Jr.

Mr. Mensing gave a report of the plans of the Philadelphia Chapter members for attending the Summer Meeting, Minneapolis, June 24 to 27, inclusive, 1930. He urged all local members to make their plans for going to Minneapolis, and pointed out the advantages of spending a vacation under such pleasant and profitable circumstances.

St. Louis

May 6, 1930. The St. Louis Chapter of the Society held its regular meeting at the Roosevelt Hotel, with President White presiding.

After the reading of the minutes of the previous meeting, the Secretary read an announcement regarding the transportation facilities to the Semi-Annual Meeting of the Society, to be held in Minneapolis, June 24 to 27.

J. P. Manahan, reporting for the Entertainment Committee, stated that for the June meeting of the Chapter which is to be given over to Ladies Night, the Committee has arranged a Bridge Party, to be held immediately after the regular meeting.

The Chapter was honored by having as their guests, H. P. Gant, Philadelphia, past-president of the Society, Dean A. Langsdorf, Washington University, St. Louis, and Dean F. Paul Anderson, University of Kentucky, Lexington.

President White called on Mr. Gant and also on Dean Langsdorf, who told of the research work being done at the Washington University in co-operation with the Research Committee of the Society.

Dean Anderson was then introduced, and as the guest speaker of the evening selected "The Heating and Ventilating Engineer is Alive" as his topic. The Dean stressed the fact that we are now passing through a stage of refinement of apparatus rather than one of new developments. After citing the refinements in the various other industries the Dean called attention to the many refinements that had been and are now being made in the heating and ventilating field.

His talk was very inspiring and thoroughly enjoyed by all present, there being 71 members and guests in attendance, the largest meeting the Chapter has ever held. The meeting was adjourned shortly after nine o'clock.

Wisconsin

April 21, 1930. The Wisconsin Chapter's regular monthly meeting in Milwaukee was featured by the reading of the various answers prepared by the members in response to a questionnaire sent out prior to the meeting relating to the heating and ventilating field and the presentation of a historical talk on heating and ventilating systems.

The guest speaker of the evening was J. F. Sprague, Sprague Engrg. Co., who discussed the different types of heating and ventilating systems over a period of 50 years. Mr. Sprague, being in the heating engineering business for over fifty-two years, gave a vivid picture of the progress of the industry and illustrated his remarks with drawings made by himself to show the various equipment described.

He began by calling attention to the first fan system used in China in 1840, which consisted of coolies running around an oven which was to be cooled. He then went into detail about the various systems of heating, telling of the advantages and disadvantages of the coke washer, made in sections like the present dry air filters. He also showed the difference between the first thermostats brought out by Johnson and Powers and their present models.

Mr. Sprague mentioned that in 1873 patents were taken out on the first steel fire-box boiler, and that the engineers in those days had no data to figure with, although all the jobs were usually supplied with plenty of heat.

He stated that the introduction of the vacuum system and temperature regulation were the greatest advancement in the heating and ventilating field.

At the conclusion of Mr. Sprague's talk, he answered the many questions put to him regarding the conditions in the heating and ventilating industry many years ago, which was followed by a rising vote of thanks by the members and guests present for the very enjoyable evening they spent in listening to Mr. Sprague.

In the contributions to the A.S.H.V.E. Research Fund listed for the calendar year 1929 in the Report of the Committee on Research, published in the March 1930 issue, partial payment was recorded on several pledges and the Committee on Research is glad to add to this annual report the names of the following organizations, who have completed payment of their pledges for the Society's research program for the past year:

Contributor	*Total Amount 1929*
American Oil Burner Assn.	$ 500.00
Buffalo Forge Company	1,000.00
Chicago Master Steam Fitters Association	1,000.00
Hoffman Specialty Company	1,000.00
Sturtevant (B. F.) Company	1,000.00

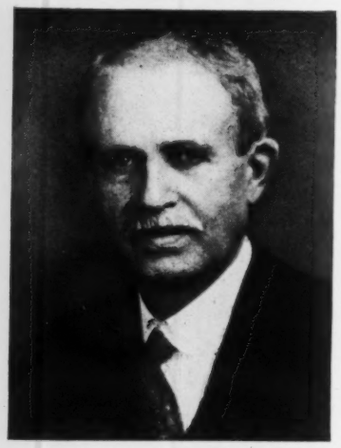
Prof. E. H. Lockwood Dies

It was with great sorrow that the news of the death of Prof. Edwin Hoyt Lockwood came to his fellow-members in the Society.

Professor Lockwood died of heart disease at the New Haven Hospital on April 17, after an illness of several days, and his passing was unexpected, as it was believed that he was on the road to recovery.

He was one of the foremost mechanical engineering experts in the country, and professor of mechanical engineering at Yale Scientific School, New Haven, Conn., at the time of his death.

Professor Lockwood was born October 31, 1865, in New Canaan, Conn., was educated in the public schools and at the



Edwin Hoyt Lockwood

New Canaan Seminary, before entering Yale University. He was graduated from the Sheffield Scientific School in 1888 with the degree of *Ph.D.*, and for the year following was a mechanical draftsman in special machinery for the Diamond Match Company's experimental plant in New Haven.

In 1890 he returned to Yale for further study in the Sheffield Scientific School and became an instructor in mechanical drafting. In 1892 he received his *M.E.* degree and in 1901 his *Ph.D.* degree. In 1900 he was made an Assistant Professor of mechanical engineering, and in 1924 an Associate Professor, and in 1927 he was appointed Professor.

During his long career on the Yale faculty he had taught nearly every subject in mechanical engineering, and had become known throughout the country for his important investigations on fuel combustion in power and heating. He took an important part in the planning of Winchester Hall and the Mason Laboratory at Yale University.

Professor Lockwood had been a member of the Society since 1915, and had always taken an active part in its affairs. He was the author of numerous papers which he presented before the Society at its annual and semi-annual meetings.

The officers and Council of the Society feel the loss of Professor Lockwood, a member who distinguished himself throughout the country, and extend their sincere sympathy to his son, Edwin H. Lockwood, Jr., of West Mansfield, Ohio, and to his daughter, Mrs. Elizabeth Lockwood Parker, of Wilkinsburg, Pa., for the great loss they have sustained.

Death of Herbert Muth

Word has just been received of the death of Herbert Muth, who, at the time of his death on December 5, 1929, was President and Treasurer of the Muth Heating and Engineering Co., Chicago, Ill.

Mr. Muth, who had been a member of the Society for the past 18 years, was born on April 27, 1878, at Plainfield, Ind. He received his education at the schools nearby.

From 1898 until November, 1908, he was connected with the Kellogg-Mackay-Cameron Co., Chicago. He later became associated with the Hutchinson Sanitary Plumbing and Heating Co., holding the position of secretary and treasurer, in charge of the heating, ventilating and plumbing divisions. He also made the plans for and supervised the installation of plumbing and heating in residence, hotel, church and Y. M. C. A. buildings in Hutchinson, Kansas.

While in business for himself in 1911 he remodeled the Reno County High School heating plant, and planned and installed heating plants in numerous schools in Kansas.

In 1916 he was with the Cameron Schroth Co., Chicago, where he remained until 1920, when he became president of the Muth Heating and Engineering Co., Chicago.

The Council and members of the Society express their sincere sympathy to his widow, who survives.

Death of William M. Foster

William M. Foster, of the Leggett-Doll-Foster Co., heating engineers and plumbing contractors, of Highland Park, Mich., died very suddenly of heart disease on April 8, 1930.

The Council and Officers of the Society were very sorry to learn of the death of Mr. Foster, who had been a member of the Society for the past 16 years.

Born at Montezuma, N. Y., Mr. Foster received his education in the primary schools and later received private instruction in mechanical engineering at Cornell University.

In 1898 he was employed in the engineering department of the Herendeen Mfg. Co., Geneva, N. Y., where he superintended the installation of both heating and ventilating apparatus in various plants.

Then in 1911 he became associated with the U. S. Radiator Corp., Detroit, manufacturers of heating boilers and radiators, serving as heating engineer.

At the time of his death Mr. Foster was connected with the Leggett-Doll-Foster Co., Highland Park, Mich., and the Society extend to them their sincere sympathy for the loss of their business associate and friend.

New Steam Tables Issued

"Steam Tables and Mollier Diagram," by Joseph H. Keenan, for pressures up to 3,200 lb. per square inch, have recently been issued by the *American Society of Mechanical Engineers*. The sources and methods of development of these tables were detailed in the February, 1929, issue of Mechanical Engineering.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the name of applicants and their references shall be printed in the next issue of the Journal of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Membership Committee as soon as possible.

When the Membership Committee has acted favorably upon a Candidate's application and assigned his grade the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 28 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Membership Committee, and in turn the Council, urge the members to assume their share of the responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned. All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some member by June 16, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary, immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
ALGREN, AXEL B., Instructor in Mech. Engrg. & Asst. Dir. of Exp. Eng. Labs., Univ. of Minnesota, Minneapolis, Minn.	F. B. Rowley M. S. Wunderlich	J. L. Blackshaw R. E. Backstrom
BARNUM, MARVIN C., Sales Mgr., Humidifier Div., Wilcolator Co., Newark, N. J. (*Advancement*).	A. S. Armagnac R. D. Tyler	Rudolph Kuhlmann P. E. Fansler
BRISSETTE, LEO A., Treas. and Genl. Mgr., Trask Heating Co., Boston, Mass.	E. F. Pierce, Jr. W. F. Gilling	R. F. Gifford I. S. Dane
BULLEIT, CHARLES R., Plumbers Supply Co., Evansville, Ind.	R. E. Legeman W. R. Stockwell	T. D. Casserly S. E. Dibble
BULLOCK, THOMAS ANTHONY, Densmore LeClear & Robbins, Boston, Mass.	J. W. Brinton T. F. McCoy	C. T. Flint H. B. Wiegner
CORRIGAN, JAMES ALOYSIUS, Student, Carnegie Inst. Tech., Pittsburgh, Pa.	S. E. Dibble E. N. Pettit	W. D. Babbitt
DARLINGTON, ALLAN PALMER, American Blower Corp., Detroit, Mich.	H. E. Paetz G. H. Giguere	H. C. Kappler W. A. Blessed
EISS, ROBERT M., Sales Engr., Buffalo Forge Co., Minneapolis, Minn.	C. E. Gausman Albert Buenger	E. B. Lewis H. E. Gerrish
EWALD, WARREN, Experimental Engineer, John J. Nesbitt, Inc., Holmesburg, Philadelphia, Pa.	A. J. Nesbitt S. E. Plewes	J. J. Nesbitt
GALLIVAN, JOHN M., Arthur E. Jones Co., Buffalo, N. Y.	Joseph Davis H. B. Roarke	L. A. Harding F. H. Burke
GRIEVES, THOMAS R., Branch Mgr., U. S. Radiator Corp., Buffalo, N. Y.	F. H. Burke Joseph Davis	D. J. Mahoney L. N. Castin
HECHT, FRANK HENRY, B. F. Sturtevant Co., Pittsburgh, Pa.	R. B. Stanger F. C. McIntosh	M. A. Benson Peter O'Neill
HENRY, ALEXANDER STEWART, JR., Mech. Engr., Radio Keith Orpheum Corp., New York, N. Y.	J. F. Dailey C. P. Bender	S. H. Mickiewicz H. G. F. Matthiessen
KINTZ, LESLIE H., Sales Engr., Johnson Service Co., Detroit, Mich.	Harry Hamlin G. H. Giguere	W. A. Blessed J. M. Stephen
LOVE, HAROLD G., Weiss & Neistadt, Chicago, Ill.	T. H. Monaghan J. H. Milliken	J. J. Hayes J. H. OBrien
MCCORMACK, PETER JOSEPH, Estimator and Engineer, W. I. Bulkeley, Inc., Cambridge, Mass.	N. J. H. Shaw W. T. Jones	P. A. L. Foulds Adolphe Ehrenzeller
MCKELVEY, DAVID MITCHELL, Consulting Engr., 60 East 42nd St., New York, N. Y.	Perry West Homer Addams	H. L. Alt J. I. Lyle

MELONEY, EDWARD J., Bowers Bros. & Co., Philadelphia, Pa.	A. H. Wichtin—*Non-Member* A. J. Jenkin—*Non-Member*	J. J. Nesbitt
ROBINSON, HARRY C., Heating and Ventilating Engr., Worcester, Mass.	H. M. Dix T. F. McCoy	E. E. Tilden Myles Standish
ROCKHOLD, KENNETH EDWARD, Mech. Engr., Austin Co., Newark, N. J.	R. S. Arnold Thornton Lewis	J. V. Cavileer C. D. Graham
SCHALL, HOWARD SHEAFER, Mgr., Erie Engrg. Bureau, Buffalo, N. Y.	F. H. Burke Wm. Roebuck, Jr.	C. A. Booth O. K. Dyer
SHIVERS, PAUL F., Chief Engr., Minneapolis-Honeywell Regulator Co., Wabash, Ind.	N. W. Calvert V. S. Day	E. J. Vermere C. H. B. Hotchkiss
STOEVER, GEORGE H., John J. Nesbitt, Inc., Holmesburg, Philadelphia, Pa.	A. J. Nesbitt J. J. Nesbitt	A. J. Jenkin—*Non-Member* J. M. Sewell
TABY, JOSEPH COURAD, Owner of Business, Second & Walnut Sts., Shamokin, Pa.	J. H. Lutz, Jr. T. J. Degnan	E. T. Selig I. H. Geiger
TULLOSS, JOSEPH C., S. H. Kress & Co., New York, N. Y.	L. E. Seeley G. A. Stetson (*ASME*)	P. W. Swain (*ASME*) F. J. Friedman
WAID, GLEN HAROLD, Scott Valve Mfg. Co., Detroit, Mich.	G. H. Giguere W. G. Boales	H. C. Kappler W. A. Blessed
WARREN, FREDERICK ANTON, Salesman, U. S. Radiator Corp., Atlanta, Ga.	E. W. Klein F. W. Clare	M. W. Wise
ZIMMERMAN, ALEXANDER H., Research Engr., E. Vernon Hill Co., Chicago, Ill.	A. L. Weixel E. V. Hill	J. J. Aeberly J. H. Bailey

Candidates Elected

In past issues of the Journal of the Society the names of the following men were listed as Candidates for Membership. The membership grade of each Candidate has been assigned by the Membership Committee and balloted upon by the Council. We are now instructed by the Council to post herewith, as required by Art. II, Sec. VIII, of the By-Laws, the following list of candidates elected:

MEMBERS

ADAMS, HAROLD EUGENE, Chief Engr., Nash Engrg. Co., So. Norwalk, Conn.

BONDY, WINFIELD S., Clarage Fan Co., New York, N. Y. (*Advancement*)

CALDWELL, ARTHUR C., Estimator & Eng., P. Gormley, Contrs., Philadelphia, Pa.

CAREY, PAUL C., Runyon & Carey, Newark, N. J.

FOSTER, JAMES M., Ilg Electric Ventilating Co., Chicago, Ill. (*Advancement*)

HADJISKY, JOSEPH M., Albert Kahn, Inc., Detroit, Mich.

HANBURGER, FRED W., Instr. in H. & V. & Plbg., College of the City of New York, New York, N. Y.

HARRIS, JESSE E., Asst. Sales Mgr., Cochrane Corp., Philadelphia, Pa.

JACKES, HERMAN D., Sales Mgr., Aerofin Corp., Newark, N. J. (*Reinstatement*)

NAGELSEN, LOU M., Western Sales Mgr., Buckeye Blower Co., Columbus, Ohio.

PFEIFFER, JOHN FREDERICK, E. Keeler Co., Williamsport, Pa. (*Advancement*)

PHILIP, WILLIAM, Asst. Heating Engr., McKellar & Blackhall, Toronto, Ont., Canada.

SANTEE, (Miss) HELEN COOPER, Asst. to Archt. & Engr., Wilkes-Barre School District, Wilkes-Barre, Pa.

SYLVAN, STIG G., Research Engr., Midwest Eng. Co., Bradford, Pa.

VETLESEN, G. UNGAR, Consulting Engr. & Secy., Federated Laboratories, New York, N. Y.

WARD, WILLIAM T., Htg. Contr., 18 Castlefield Ave., Toronto, Ont., Canada.

ASSOCIATES

HAYDEN, CARL F., Barber-Colman Co., Rockford, Ill.

HUSTOEL, ARNOLD MALVIN, Baltimore & Ohio R. R., Chicago, Ill.

JOHNSTON, JAMES H., Branch Mgr., U. S. Radiator Corp., Harrison, N. J.

KRUSE, ROBERT W., Kruse Co., Indianapolis, Ind.

MARKS, ALEXANDER A., Asst. Sales Mgr., Richmond Radiator Co., Philadelphia, Pa.

OHNELL, ERNEST, Jr., Sales Mgr., Midwest Mfg. Co., Bradford, Pa.

PANCOAST, HENRY B., Jr., Treas., Henry B. Pancoast Co., Philadelphia, Pa.

RANDALL, HERBERT N., Sales Engr., Warren Webster & Co., Detroit, Mich.

SCHERNBECK, FRED H., Salesman, William Bros. Boiler & Mfg. Co., Nicollet Island, Minneapolis, Minn.

WHITE, JAMES J., Vice-President, McArdle & Cooney, Inc., Philadelphia, Pa.

JUNIORS

BUTT, RODERICK E. W., Carrier Engrg. Co., Ltd., London, England.

FAMILETTI, A. ROBERT, Mensing & Co., Philadelphia, Pa.

FOULDS, SAMUEL T. N., The Trane Co., Boston, Mass.

JOHNSON, CARL ERIC, Buffalo Forge Co., Philadelphia, Pa.

PORTER, RICHMOND CLAY, Research Asst., Engrg. Dept., Univ. of Kentucky, Lexington, Ky.

TEN BROOK, CHARLES SPAULDING, The Trane Co., LaCrosse, Wis.

Heating · Piping and Air Conditioning EDITORIALS

Modernization of Plants

A few days ago we visited a manufacturing plant whose ventilating equipment was so worn it was about ready to fall apart, yet the factory continued to function and to pay a dividend each year. It was learned that all of the equipment of the place had been written off long ago. The owners argued that this was an economical procedure as the equipment did not cost them a penny and because of this they were deaf to the importunities of sales engineers who were capable of showing them how to turn out a better product, with fewer interruptions, less power and less labor per unit of product.

Such cases have been all too typical of many industrial plants in the past years. But 1930 marks a new era in manufacturing. The year 1930 should be one of modernization. From the president of the United States down through bureaus, societies, associations and committees, the idea has been broadcast that modernization not only embodies the spirit of America but is an economic and dividend-paying movement.

"Modernization pays" is not merely a saying or slogan. Large numbers of concerns who have modernized their plants in recent months have found that modernization often pays surprising dividends. A large heating manufacturer made some investigations recently and cites several following instances: In an office building, modernization of the heating plant resulted in a saving of 44 per cent in operating costs. In a knitting mill, introduction of modern methods resulted in a saving of over $17,000 a year. In an arcade there was the yearly saving of about $6,000 following a modernization program that cost about $5,000. In an office building there was a saving of $1,100 per season following an investment of $1,300 in new equipment. In a shirt factory there was a saving of $600 per year in the heat bill as a result of an investment of almost negligible amount. These instances are taken from the heating field. Proportional savings can be made (and are being made) following the principles of modernization in piping and air conditioning.

Principles of Simplified Practice

The division of simplified practice of the National Bureau of Standards of the United States Department of Commerce states that many manufacturers do not have the slightest conception of the character of the work of the Bureau, although many instances are on record that show the benefits of simplified practice.

Opportunities for simplified practice among manufacturers is apparently unlimited. It is maintained that the concentration on production of a few items that are in large and steady demand tends to smooth off the peaks and valleys of production operation and that this in turn tends to stabilize labor conditions and reduce fluctuation and turnover. The division of simplified practice recommends that technical publications explain the character of this service.

It has no regulatory or police powers; it does not initiate projects. When a project is undertaken, a detailed survey is made to show the demand for each type or size of product made by the entire industry, and a committee of manufacturers formulates a simplified list of sizes and varieties, usually much smaller than the existing number of varieties, but sufficient to cover all ordinary and reasonable demand. The division then calls a general conference and invites manufacturers, distributors, representatives, users and others interested in the particular commodity. If the ground work has been done properly, the simplified list is approved by those who attend the general conference and thereby becomes a simplified practice recommendation, subject to written acceptance by the industry as a whole.

For instance the Texas Hotel Association recently approved a resolution endorsing the application of simplified practice to the hotel industry. They propose to consider standards and performance specifications of mechanical as well as of non-mechanical equipment. Other business and industrial associations will watch the effects of such recommendations with interest.

Unusual Structures

If the statement be true that "What man can imagine he will do," then heating and air conditioning engineers and contractors, in the next few years, may be called upon to apply their ingenuity to designing equipment for, and installing it in, buildings of quite unusual design. Some such buildings already have been constructed. Some of them present new and unusual problems.

For instance, a new note was sounded in building construction some months ago with the introduction of the idea of skyscrapers without windows. Among a certain group of engineers and architects it was given serious consideration. Another case is the proposal

of constructing a dwelling practically all of windows with no foundation, with the entire structure supported on a central mast. This idea, which was received with some levity, is being worked out as a practical experiment. Now an American architect has designed, and proposes to construct, one or more loft buildings with glass curtain walls, light in weight and having many other novel features.

Charles Morgan, A. I. A., Chicago, predicts the skyscraper bridge. "Why," asks Mr. Morgan, "should one build a bridge so low that it has to be lifted or opened when vessels pass? Why not make each pier a skyscraper apartment or office building with arches so high that any vessel can pass without delay?" Mr. Morgan believes that such structures will some day be a reality, and that the idea of entering buildings from the top will be found just as logical as entering them from the base.

It is interesting to watch these developments, and considering the rapid changes in heating, piping and air conditioning in the last few years, who knows what fifteen years in the building industry may bring forth or how they may affect heating and air conditioning practice?

A Hundred Years of Research

It is interesting to consider the theories held by early investigators in the fields of electricity and heat, and to note that their hypotheses classified both as material bodies. Both Newton and Franklin conceived electricity as an exceedingly subtle fluid, and until the experiments of Joule, Mayer and others established the status of heat as a form of energy, physicists generally considered it also a fluid.

As late as the middle of the nineteenth century a scientist of note expressed his theory of electricity thus: "I am disposed to consider with Franklin, that electricity has a positive entity; that it is a subtle body condensed on the surfaces and through the pores of all bodies in virtue of some of the forces of matter." At the same time, however, this writer seemed inclined to consider heat, or "caloric," as a "principle, or force," rather than as a fluid. But he was careful to differentiate between "caloric" and "heat," much as we today differentiate heat and temperature, though he was not always entirely consistent.

"We are absolutely ignorant of the nature of the principle of heat," he avers; and by the "principle of heat" he means "caloric," as distinguished from *heat*, the *effect*. Continuing, he says: "Our senses make us familiar with two conditions,—*heat* and *cold*. These are precisely the same forms of expression in relation to *caloric* as *positive* and *negative* are to *electricity*."

Not so long ago the mind of man inclined toward elaboration of all phenomena. Water, fire, air, lightning, and countless other things were called "elements." The modern trend is toward simplification. Even ten years ago several scores of "elements" were classified; today the newer atomic hypothesis questions the existence of more than one, speaking in the sense of the ultimate.

Likewise, there is today a disposition to identify all energy with a single force, though it must be admitted that the identification has not as yet progressed out of the realms of speculation. Some scientists are convinced that the force of gravity, of magnetism, of heat, et cetera, *must be* the same force manifest in different ways, but as yet not even a satisfying hypothesis has been offered.

When we remember that as short a time ago as 1800, after some 3,000 years of thought, the theory of heat as a material substance was generally accepted, and that combustion was considered a process in which a burning body gave off a substance called "phlogiston," it should not be discouraging that a hundred years of research has not solved all the mysteries of the universe. The facts are that our rapidly developing civilization has demanded that our efforts be directed first toward the devising of methods whereby our admittedly scanty knowledge of fundamentals may be practically utilized. Research in the realms of "pure science" has not been entirely neglected nor wholly unproductive, and, compared with the accomplishments of past centuries, the results should be highly gratifying, even though there still remains much to be learned.

Training in Maintenance

In the maintenance of an industrial plant, getting employes to do things right is an art. It is an executive's job. He must be a leader and trainer of men. The operating engineer should not expect men to serve him perfectly at all times unless they are given training in the particular plant in which they are employed. Training a maintenance crew requires thought and energy.

This does not mean that the operating engineer should conduct classes and use all the equipment of a modern school. It does not mean that he should devote a large part of his time to giving instruction. But the most effective teaching of the maintenance crew is that acquired in the routine of a day's work. If given unfamiliar tasks, and given to understand that the company will notice and take pride in his success, and with a little direction here and there, the maintenance worker will gradually acquire skill which in future days will enable him to relieve the head of his department. Keeping logs, plotting loads, curves and computing the day's performance, can, with a little instruction, be delegated to a foreman and he will become confident in the particular duties he is asked to perform. The capabilities of each man should be studied, but the main point is that men cannot advance unless given responsibility. With a clear idea of the qualifications of each man, and plans to develop each one, the maintenance engineer should be able to render a much better service to his employer. He will then function as an executive rather than a workman.

PRACTICAL PIPING PROBLEMS

Controlling the Supply for a Long Steam Line

by **W. H. WILSON**

Controlling Steam Mains

The accompanying illustration shows an arrangement of piping and valves that can be used for controlling the supply for a long steam line, to an advantage, under certain conditions.

In this particular case the steam main was eighteen hundred feet long. During regular working hours a large amount of steam at 180 pounds pressure was required for steam-driven machinery. At the close of the regular working day, during the winter season, a small amount of steam at a maximum pressure of 40 pounds was required for process work during the night, and days when the plant was not in full operation. During the summer season, no steam was required after the close of the regular working day until the plant resumed normal operation.

The main shut-off valve for this steam line was originally equipped with a by-pass. This was removed and a steel plate bolted in its place, with two pipe thread tappings opposite the by-pass ports in the body of the valve, the thickness of the plate being sufficient to provide stock for the pipe thread tappings. A reducing valve was installed as shown, of the size of the by-pass connection, the arrangement of the piping depending on the conditions and the location of the main valve.

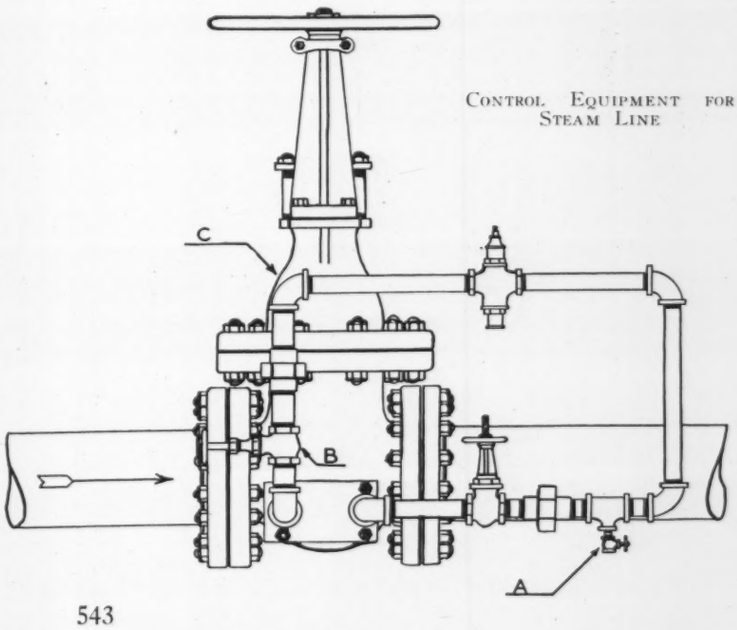
It is recommended that the reducing valve be placed at the highest point, to avoid condensation collecting ahead of the valve. The drain valve, shown at *A*, affords a convenient way of releasing the accumulated pressure when the small reducing valve is shut off and is being disconnected for repairs, or other purposes.

The method of operation was to put the small reducing valve in use, set at 40 pounds pressure, inlet and outlet valves being left open. The main valve *C* was then opened and the steam line was ready for use under the daily working conditions. At the close of the regular working day, during the winter season, the main valve was closed. During the time this valve was closed the small reducing valve supplied steam, enough in quantity and pressure, to meet the requirements of that period. At the beginning of the regular working day, the main valve was opened and the full quantity and pressure of steam was available. The inlet and outlet valves for the small reducing valve were left open. At this time the small reducing valve was automatically closed, but ready at any time to automatically open and resume control, should the main valve be closed.

During the summer season, at the close of regular working hours, both the main valve *C* and the inlet valve *B* of the small reducing valve were closed, as no steam was required on the line. When steam was required on the line at the commencement of regular working hours, the small valve *B* was opened and the maintenance man, after taking care of the drips and trap at the end of the line, performed some of his other duties and then came back to the main valve which could be opened wide as the steam line then had 40 pounds steam pressure controlled by the small reducing valve.

The use of the small reducing valve enabled a saving to be made, when in use, by carrying a lower steam pressure on the long pipe line, which naturally meant less condensation losses and a low steam pressure is often advisable on large pipe lines, outside of regular working hours, as fewer maintenance men are at hand in case unforeseen troubles arise. This reducing valve was also a help to the maintenance men by assisting to get the steam pressure turned on the steam line, quickly, conveniently and safely. A large drip pocket and a large capacity steam trap on the extreme end of the pipe line was used to advantage in conjunction with this small reducing valve, for getting steam pressure on the line quickly. The size of the small reducing valve depends on conditions. In this particular case the size of the main valve was 8 inches and the reducing valve 1½ inches.

This method of handling the steam line may have caused some extra work in repacking the expansion



CONTROL EQUIPMENT FOR STEAM LINE

joints, due to temperature changes. By using a good grade of packing and lubricating the sleeves of the expansion joints periodically the extra work required should be scarcely noticeable.

In case the main valve is not provided with a by pass connection, the valve body may be of sufficient strength and weight to permit tapping for the connections or they can be tapped in the pipe on either side of the valve.

A Problem on Boiler Horsepower

"Now, boys," says the Boss, "here is a little problem and I want to see what you can do with it."

"In the first place I have a little factory down here which requires, for a certain process which they use, about 500 gallons of 180 F water every four hours. It takes about 5 minutes to run the water into the vat and I want to know what method of heating this water would throw the least load on the boilers because they are short of steam now."

Bill, who is usually pretty quick at figures, spoke right up and said, "Why, it takes about 3½ sq. ft. of radiation to equal one gallon of water so the equivalent direct radiation would be 500 × 3½ or 1750 sq. ft."

Jim is not quite so quick and he figured it out by changing the water to pounds, multiplied this by the temperature rise and divided by 240. This is what he got:

$$\frac{500 \times 8\,1/3 \times (180° - 50°)}{240} = 2257 \text{ sq. ft.}$$

Bill finally admitted that Jim was right but the temperature rise was a little more than usual and consequently his rule-of-thumb figure of 3½ sq. ft. to a gallon in this case was a little low.

Jim went on and reduced this to boiler horsepower by dividing by the B.tu for a horsepower instead of the B.tu for a sq. ft. of radiation and this gave

$$\frac{500 \times 8\,1/3 \times (180° - 50°)}{34{,}400} = 15.7 \text{ b.hp.}$$

"But," said the Boss, "your equivalent direct radiation and boiler horsepower are based on one hour and consequently it would take one hour to heat the water with the loads you have calculated. If an instantaneous heater were used what would be the load and if a storage heater were used what should be the size for the smallest boiler load possible?"

Bill took the instantaneous heater which heats the water as it flows through and, allowing 5 minutes to fill the vat, Bill decided that since 5 minutes was 1/12 of an hour it would produce a boiler load during the 5 minutes the water was running of 12 times the hourly load since all the heating must be done in 5 minutes instead of an hour.

This gave for equivalent direct radiation:

$$2257 \text{ sq. ft.} \times 12 = 27{,}084 \text{ sq. ft.,}$$

and for boiler horsepower

$$15.7 \times 12 = 188.4 \text{ b. hp.}$$

The Boss sadly shook his head: "That is nearly all the boiler capacity there is in the whole plant," said he. "Have we got to shut down every time we fill the vat?"

Jim, however, had also been figuring and came out with a storage tank proposition based on storing 500 gallons and heating the water in one hour which reduced the boiler load back to its original figure of 2,257 sq. ft. of e.d.r. or 15.7 b. hp. This was much less of a load on the boiler than produced by the instantaneous heater.

"Well," said the Boss, "Jim is getting better but you must remember that you cannot draw out all the contents of a hot water tank and hold up the temperature because the incoming cold water will begin to cool off the tank water. If you can run off 75 per cent of your hot water stored in the tank before this cooling becomes noticeable you are doing well."

"Then," said Jim, "you will require a slightly larger tank. Assuming the tank capacity as 100 per cent and that 75 per cent can be run off without a serious drop in temperature, then the 500 gallons run off must be 75 per cent of the total tank capacity. And dividing 500 gallons by 75 per cent we get a storage tank capacity of

$$500 \div 75 \text{ per cent} = 667 \text{ gallons}$$

or say a 700 gallon tank."

"Now you are talking sense," said the Boss.

"But," exclaimed Bill, "we have 4 hours to heat the water so that the boiler load would only be ¼ of 15.7 b. hp. or

$$15.7 \div 4 = 3.9 \text{ b. hp.}$$

and," said Bill, "I don't think you can get a load any less than that no matter how you do it."

"Well, Bill," said the Boss, "I think you have the right answer. If we put in a 700 gallon storage capacity tank with a coil to heat 125 gallons per hour we are doing pretty well as far as loading the boilers is concerned."

Just then Jim spoke up. "I don't see how you are going to heat just 125 gallons per hour," said Jim. "If the coil is made big enough to heat 125 gallons per hour, it will heat more than 125 gallons the first hour and less than 125 gallons the fourth hour."

"How do you make that out?" said the Boss.

"Why," said Jim, "during the first hour when the tank is cold and the water in the neighborhood of 70 or 80 degrees average, the temperature difference between the steam in the coil and the water (assuming steam at 220 F) will be

$$220° - 60° \text{ or } 160°$$

but during the last hour when the water averages somewhere around 170 the temperature difference will be only

$$220° - 170° \text{ or } 50°$$

and with over three times the temperature difference the first hour as compared to the last hour the efficiency of the coil should be over 3 times as high during the first hour as it would be during the fourth hour."

"The average coil rating," went on Jim, "is based on raising water from 50 to 150 F or an average temperature of 100 deg. which, subtracted from the steam temperature of 220 F, makes an average temperature difference of

$$220 \text{ F} - 100 \text{ F} = 120 \text{ F}$$

but our coil during the first hour will have an average temperature difference of 160 F or about 30 per cent

more than the average coil under average conditions and this would increase the transmission and boiler load approximately 30 per cent as well or

3.9 b. hp. + 30% of 3.9 or 5.07 b. hp.

which will be the boiler load during the first hour."

"Jim," said the Boss, "you are so dog-gone right, that I have got to admit you thought of something I had entirely overlooked. But I tell you I can beat all the figures so far presented."

Everyone thought and thought and could see no way to better the results. Finally the Boss said, "Suppose I put in a 1,350 gallon tank and give it 12 hours at night to heat, carrying the water hot all day until it is used. Then what is the load to heat 1,000 gallons in 12 hours at night and what will be the load for radiation loss on the tank during the day while the hot water is stored?"

Just then the five o'clock whistle blew and the discussion terminated for the time being.—*H. L. Alt.*

Industrial Trust Company Building, Providence, R. I.

The Industrial Trust Company Building of Providence, R. I., uses both mechanical and window ventilation. It is not cooled in summer. The capacity of the direct radiation is 52,432 square feet, indirect heating capacity 39,584 square feet. The ventilating system is equipped with five supply fans, delivering 95,800 cubic feet per minute and exhaust fans with a total capacity of 129,100 cubic feet per minute.

Conventions and Expositions

National District Heating Association: Annual convention, June 3-6; Coronado Hotel, St. Louis, Missouri. Secretary-treasurer, D. L. Gaskill, 603 Broadway, Greenville, Ohio.

Heating and Piping Contractors National Association: Annual convention, June 16-19; Hotel New Yorker, New York City.

Association for Correlating Thermal Research: Annual meeting, June 16-19; Hotel New Yorker, New York City. Secretary-treasurer, F. C. Houghten, 4800 Forbes St., Pittsburgh, Pa.

American Society of Heating and Ventilating Engineers: Summer meeting, June 24-27; Curtis Hotel, Minneapolis, Minn. Secretary, A. V. Hutchinson, 51 Madison Ave., New York City.

World Power Conference: June 16-25; Berlin. Program Committee, Room 1818, 29 W. 39th St., New York City.

American Society for Testing Materials: Annual meeting, June 23-27; Haddon Hall, Atlantic City, N. J. Secretary, C. L. Warwick, 1315 Spruce St., Philadelphia, Pa.

Stoker Manufacturers Association: Nov. 11-13, Greenbrier Hotel, White Sulphur Springs, West Virginia.

National Association of Practical Refrigerating Engineers: Annual convention and exhibition, Nov. 11-14; Hotel Peabody, Memphis, Tenn. Secretary, E. H. Fox, 5707 W. Lake St., Chicago.

Recent Trade Literature

Air Conditioning: Parks-Cramer Company, 1102 Old South Bldg., Boston, Mass.; an attractive and well-illustrated 110-page book on air conditioning in printing and lithographic plants. The chapter headings include purpose of air conditioning, properties of paper as affected by atmospheric conditions, atmospheric conditions in the press-room, the bindery, and the storeroom, co-operation needed between the paper manufacturer, the wholesaler, and the printer, fundamentals of humidity, instruments, health and comfort as affected by atmospheric conditions, air conditioning apparatus (early and modern), and automatic regulation. An appendix contains a great deal of information and data for the air conditioning engineer, especially applicable to printing plants.

Blowers: The Warm Air Furnace Fan Company, 6511 Cedar Ave., Cleveland, Ohio; circular describing a centrifugal furnace blower which features by-pass louvres to provide free area for gravity flow when the fan is not running, said to be particularly applicable to temperature variations. A data sheet giving dimensions, capacities, etc., is included.

Boilers: The Bryant Heater & Mfg. Company, 17825 St. Clair Ave., Cleveland, Ohio; a twenty-page handbook on heating buildings with gas boilers and one on heating water with gas boilers. These booklets give complete descriptions of this company's gas boilers and present information on selecting the proper size of boiler. The book on heating water gives the characteristics of several kinds of hot water loads.

Boilers: Heating Systems Manufacturing Corporation, Joliet, Illinois; circular on a welded steel boiler designed for oil or gas. Ratings, data and price list are included.

Boilers: The James Leffel & Co., Springfield, Ohio; 24-page bulletin describing horizontal return tubular internally fired, or Scotch marine type, boilers designed especially for bakeries. A complete and fully illustrated description of these portable boilers is given. Oil and wood-burning boilers, an automatic under-feed stoker, and two classes of horizontal